FINAL TECHNICAL REPORT
PROJECT NO. A-8013

ADVANCED MICROWAVE PRECIPITATION RADIOMETER (AMPR) FOR REMOTE OBSERVATION OF PRECIPITATION

By:
J. A. Galliano and R. H. Platt

Final Report for Period 31 December 1987 - 31 December 1990

Prepared for:
NASA George C. Marshall Space Flight Center
MSFC, Alabama 35812

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FOREWORD

This final technical report was prepared by the Electromagnetics Laboratory of the Georgia Tech Research Institute, Georgia Institute of Technology under Contract NAS8-37142. The contract was initiated by the Atmospheric Sciences Division of NASA Marshall Space Flight Center. The contract was administered by Dr. Roy Spencer, Code ED43, of the Atmospheric Physics Branch.

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The views and conclusions contained in this report are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of NASA Marshall Space Flight Center or the U.S. Government.

PREFACE

This report describes the design, development, and tests of the Advanced Microwave Precipitation Radiometer (AMPR) operating in the 10 to 85 GHz range specifically for precipitation retrieval and mesoscale storm system studies from a high altitude aircraft platform (i.e., ER-2). The primary goals of AMPR is the exploitation of the scattering signal of precipitation at frequencies near 10, 19, 37, and 85 GHz together to unambiguously retrieve precipitation and storm structure and intensity information in support of proposed and planned space sensors in geostationary and low earth orbit, as well as storm-related field experiments.

The development of AMPR will have an important impact on the interpretation of microwave radiances for rain retrievals over both land and ocean for the following reasons:

(1) A scanning instrument, such as AMPR, will allow the unambiguous detection and analysis of features in two dimensional space, allowing an improved interpretation of signals in terms of cloud features, and microphysical and radiative processes;

(2) AMPR will offer more accurate comparisons with ground-based radar data by feature matching since the navigation of the ER-2 platform can be expected to drift 3 to 4 km per hour of flight time; and,

(3) AMPR will allow underflights of the SSM/I satellite instrument with enough spatial coverage at the same frequencies to make meaningful comparisons of the data for precipitation studies.

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INTRODUCTION

Scattering-induced brightness temperature depressions from precipitation are strong enough in the millimeter wave region to provide a meaningful contrast with the radiometrically warm land background. Higher frequencies (37 GHz and above) yield greater cloud penetration because of less sensitivity to small non-precipitating ice. Lower frequencies (18 GHz and below) when used with the higher frequency channels allow an unambiguous separation of the rain signal from wet ground and water bodies, because the emissivity decreases with frequency for precipitation (volume scatterer), while the emissivity increases with frequency for water (emissive surface).

Figure 1 provides evidence of how different frequencies of radiation might respond to different heights within a rain system. As the frequency decreases, the depth in the cloud from which most of the information is obtained increases. For precipitation measurements, one would like the response to be from a level as close to the ground as possible. However, the brightness temperature contrast between rain and the warm land background is small at such a low level. At the other extreme (highest frequency), the contrast temperature between the storm and land background is very strong; but it is not likely well related to the precipitation rate near the surface. Therefore, it is advantageous to select an intermediate frequency (such as 37 GHz) that has a relative strong signal due to attenuation by precipitation, and is still responsive to processes from deep enough in the cloud to be well related to rain rate.

Figure 1 suggests a need for an instrument to cover the frequency range of 10 to 85 GHz in order to investigate and better understand the scattering effects of precipitation on the convective scale. In addition, a suitable high altitude version of this instrument would impact the design requirements for, and the data analysis from, future proposed spaceborne instruments. These issues were the primary justifications for the development of the Advanced Microwave Precipitation Radiometer (AMPR). Table 1 summarizes the key technical issues of the AMPR which were addressed during the course of this program.

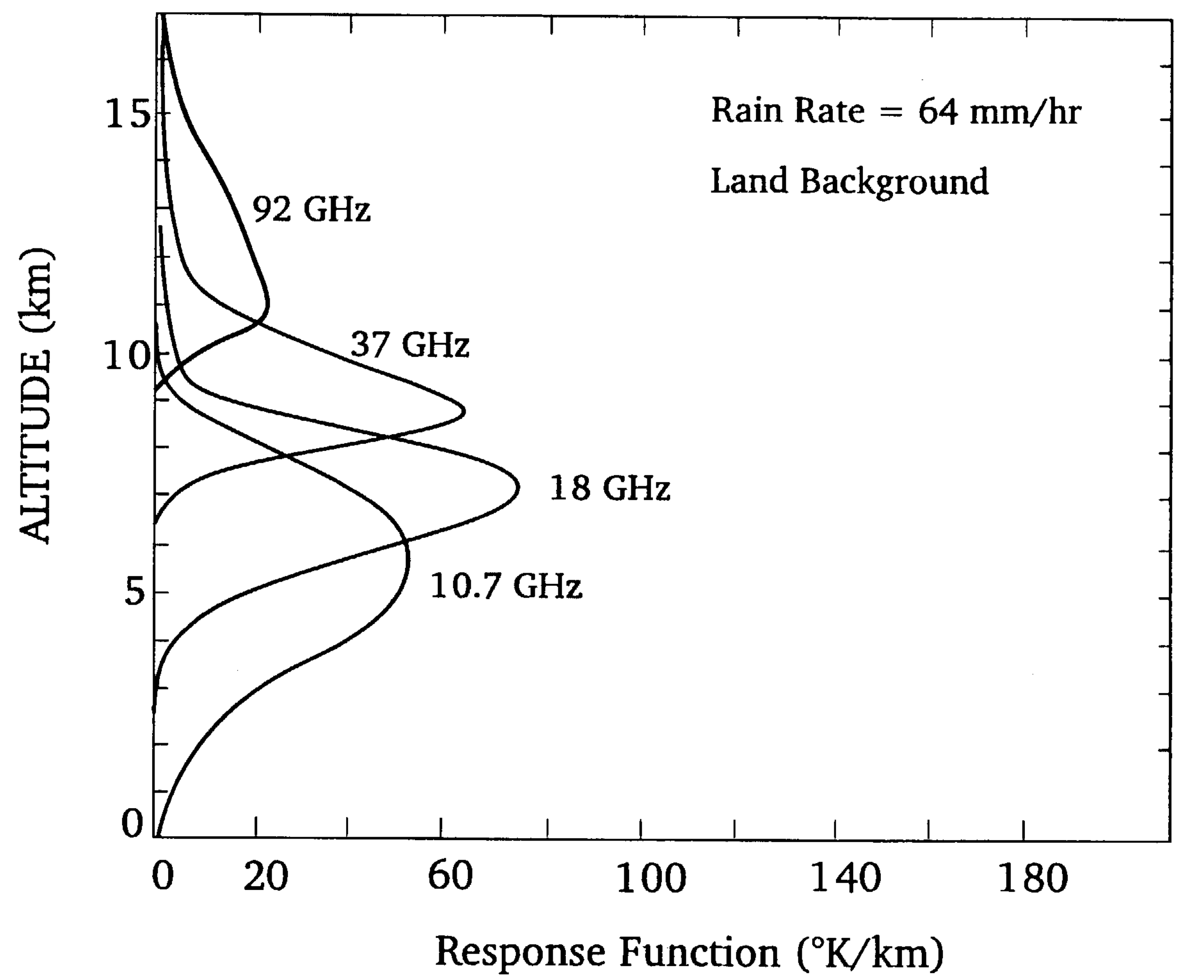


Figure 1. Response(Weighting) Function for Severe Storm (Multiple Frequencies vs Altitude)

TABLE 1. ADVANCED MICROWAVE PRECIPITATION RADIOMETER (AMPR)
KEY TECHNICAL ISSUES

Task	Issue	Design Approach
Antenna design	Implement MFFH design (note 1)	Lens, reflector, Gaussian optics
Scanner system	Speed constraint	Retrace or continuous
Calibration sequence	Dead time cycle	Periodic or continuous
Calibration loads	Type loads	Emissive or noise diode
Receiver system	Detection scheme	Direct or down convert
Data processing	GTRI/MSFC interface	Imaged data plus calibration data
Ground test	GTRI design	Portable (GIT or in-field)
ER-2 platform	AMPR/hatch compatible (note 2)	Hatch/rack, power, EMI

Note 1. Multifrequency feedhorn (MFFH) is identical antenna used on SSM/I spaceborne radiometer.

Note 2. Design AMPR package to be compatible with ER-2 HI-camp hatch.

TECHNICAL DISCUSSION

Figure 2 provides a pictorial of the AMPR system technical parameters which were considered during the initial design phase of the program. Design experiences gained from an earlier NASA radiometer program, i.e. the Advanced Microwave Moisture Sounder (AMMS), were incorporated into the development of the AMPR instrument. Each of the subsystems illustrated in Figure 2 are fully described in this section.

RF SYSTEM

The initial design study included an investigation into using the SMMR feedhorn rather than the SSM/I design. The SMMR offered the potential for ten channels in the 6.6 to 37 GHz region, i.e. five frequencies with dual orthogonal polarization at each frequency. However a decision by the sponsor to include 85.5 GHz as the highest frequency channel complicated the antenna design because a folding mirror was required to fold the optics in the lower frequency bands and to pass the 85.5 GHz band through the mirror. Further investigations revealed that insufficient space was available in the ER-2 HI Camp hatch to locate the 45° folding mirror between the horn and the illuminating lens.

At this point the antenna design effort was redirected toward implementing the SSM/I multifrequency feedhorn with a lens designed to obtain the desirable spatial resolution. Since the SSM/I MFFH included the higher frequency band, then the antenna design was more easily achievable within the size constraints of the ER-2 hatch. A separate horn/lens design was required for the lowest band of 10.7 GHz because the SSM/I feedhorn's lowest frequency band is 19.35 GHz.

It was necessary to design a dual lens antenna capable of fitting within the hatch such that the sum of the lenses diameters did not exceed 15 inches, which was the maximum opening available in the hatch bottom. Setting D_1, equal to the 10.7 GHz lens diameter and D_2 equal to the MFFH lens diameter and assuming that the spatial resolutions at 10.7 and 19.35 GHz are designed to be identical, then

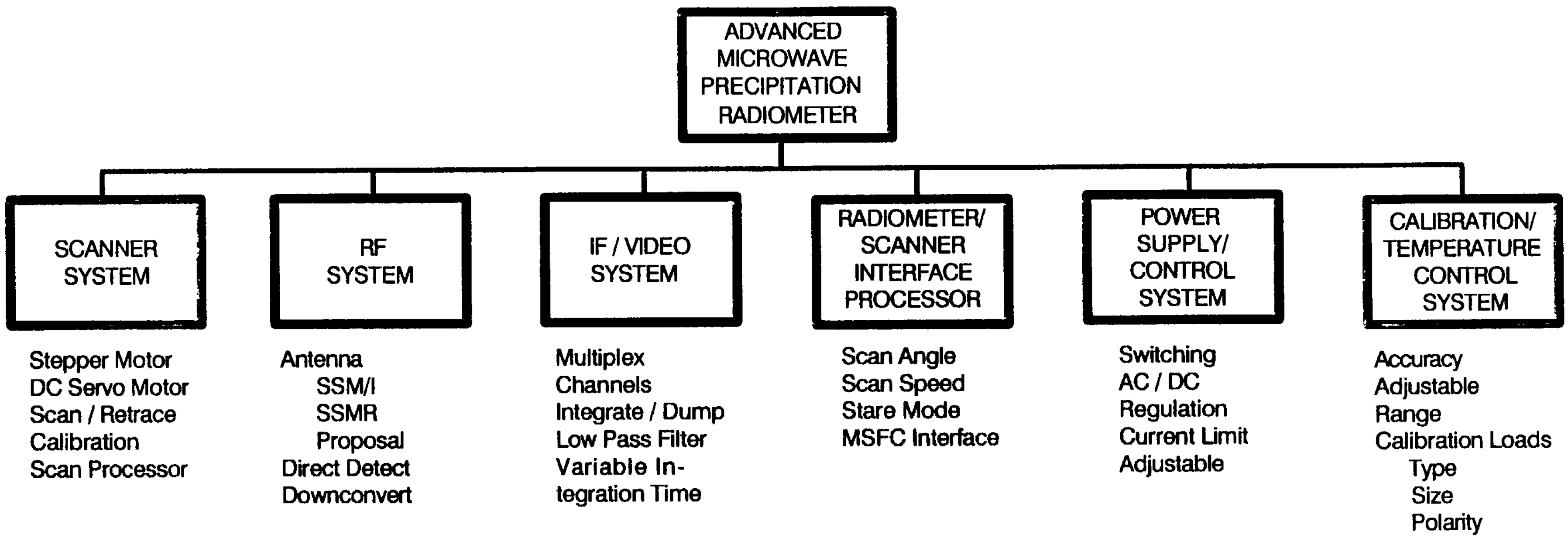


Figure 2. Advanced Microwave Precipitation Radiometer (AMPR) System Parameters

$$D_1 + D_2 = 15.0 \text{ in.}$$

or

$$D_1 + \left(\frac{\lambda_2}{\lambda_1}\right) D_1 = 15.0 \text{ in.}$$

for $\lambda_1 = 28.04$ mm (10.7 GHz band)

and $\lambda_2 = 15.50$ mm (19.35 GHz band).

Therefore $D_1 = 9.7$ in. and $D_2 = 5.3$ in. for the 10.7 GHz lens antenna aperture and the SSM/I MFFH lens antenna aperture, respectively. Table 2 summarizes the spatial resolution for each of the four frequency bands assuming an aircraft altitude of 20 km or 65,600 ft.

A major design issue for the RF system was a determination of the sensitivity required to achieve a minimum temperature resolution (ΔT_{min}) of 1.0K as specified by the sponsor. It can be shown that the total power radiometer's sensitivity (F_{dB}) is given by:

$$F_{dB} = 10 \log \left[\left(\frac{\Delta T_{min}}{T_o}\right) (\beta\tau)^{1/2}\right].$$

This assumes that the radiometer's antenna temperature (T_A) is equal to the ambient temperature (T_o) and that the system's normalized gain variation is negligible. Table 3 summarizes the required sensitivity for each of the four channels assuming a maximum temperature resolution of 1.0K.

The sensitivity goals given in Table 3 are based on a maximum temperature resolution of 1.0K. By achieving lower sensitivity levels, the resolution is improved beyond the system specification. Figure 3 is a block diagram of the AMPR RF system for each of the four frequency bands. Table 4 summarizes the receiver sensitivity for each channel based on measurements performed during the test

TABLE 2. AMPR SPATIAL RESOLUTION FOR D_B EQUAL TO THE ALONG TRACK BEAMSPOT DIAMETER

Channel (GHz)	$\theta_{3\,dB}$ (radians)	D_B (meters)
10.70	0.139	2,780
19.35	0.139	2,780
37.10	0.074	1,480
85.50	0.032	640

Note 1. θ_{3dB} (radians) = 1.222 λ/D, for D = antenna diameter and λ = signal wavelength.

Note 2. $D_B = \theta_{3\,dB}$ x aircraft altitude, for aircraft altitude = 20 km.

TABLE 3. AMPR SENSITIVITY REQUIREMENTS FOR
ΔT_{min} = 1K AND T_A = 300K

Channel (GHz)	IF BW (β in MHz)	Integ. Time (τ in ms)	F_{dB} (max.)
10.70	100	50	8.7
19.35	240	50	10.6
37.10	900	50	13.5
85.50	1400	50	14.4

Note 1. IF BW specified per SSM/I requirements.

Note 2. Integ. time based on ER-2 altitude of 20 km, aircraft speed of 500 mph, and scan angle of ± 45° and contiguous imaging at 85.5 GHz.

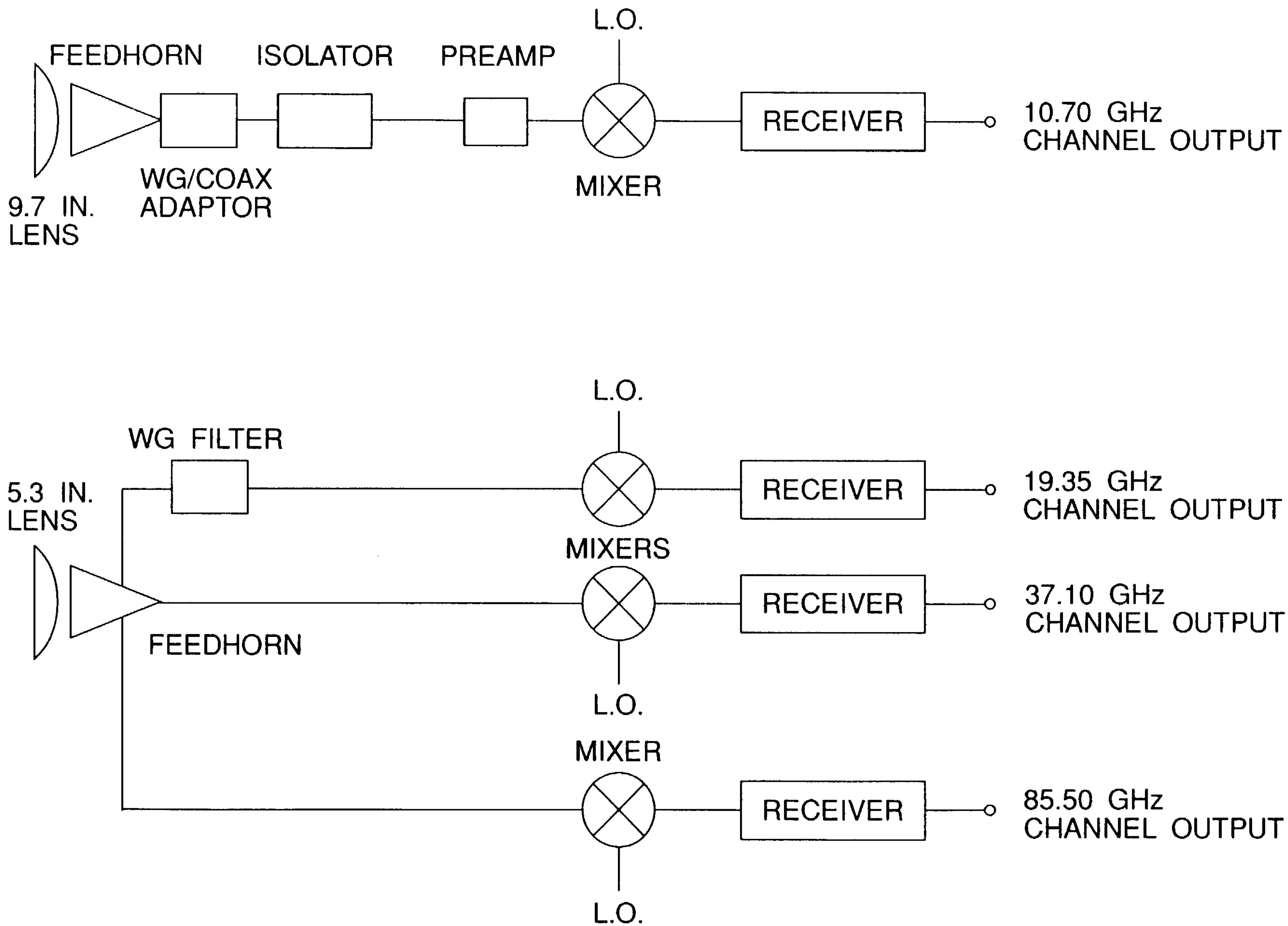


Figure 3. AMPR RF System Block Diagram.

TABLE 4. AMPR TEMPERATURE RESOLUTION ACHIEVED
FOR F_{dB} MEASUREMENTS

Channel (GHz)	Sensitivity F_{dB}	Sensitivity F_{ratio}	IF Bw (β in MHz)	ΔT_{min} (°K)
10.70	3.4	2.188	100	0.30
19.35	5.8	3.802	240	0.35
37.10	5.6	3.631	900	0.20
85.50	6.9	4.898	1400	0.23

Note 1. $$\Delta T_{min} = T_o\, F_{ratio} \left[\frac{1}{\beta\tau} + \left(\frac{\Delta G}{G}\right)^2 \right]^{1/2}$$

T_o = ambient temperature = 300K

τ = 50 ms

$\frac{\Delta G}{G}$ = nominal gain variation = 0.01%

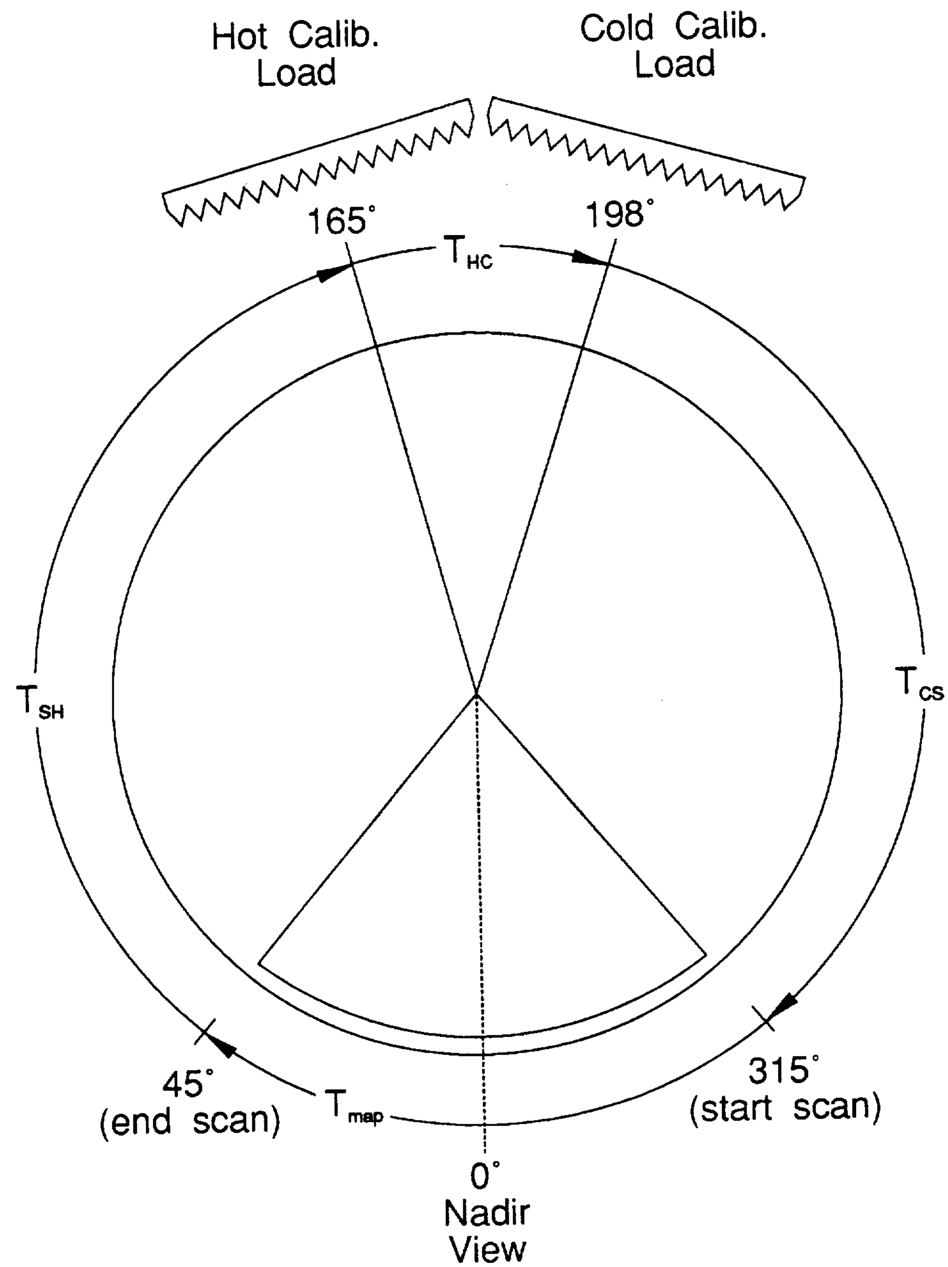
phase of the program. It can be shown that for a maximum gain variation of 0.05%, (easily achievable with current component technology) a minimum temperature resolution of 0.44K occurs at 10.7 GHz and a maximum temperature resolution of 0.76K occurs at 85.5 GHz.

SCANNER SYSTEM

The geometry for the AMPR scanner is depicted in Figure 4. In this configuration the AMPR scanning cycle begins at 315°, maps through the nadir (downward looking) view, and finishes at 45°. Upon command, the scanner's metal reflector swings up to view each of the two calibration loads for a designated period of time. The scan routine is designed to accelerate the reflector between the end scan point and the point at which the beam initially intersects the hot calibration load. At that point the reflector is made to decelerate to a complete stop at the center of the hot calibration load. This routine is repeated for the cold calibration load.

Figure 5 is a pictorial view of the AMPR scanner mounted in the ER-2 HI-CAMP hatch with the extended fiberglass fairing as shown. The 15.50 inch dimension represents the rotating elliptical reflector's major axis. A maximum scan extent of ± 40.59° about nadir is available. Figure 6 is a side looking view of the AMPR showing the SSM/I feedhorn (upper) and the 10.7 GHz feedhorn (lower). Dual calibration loads situated above the scanner are provided for calibration.

Figure 7 shows the scanner system block diagram. A scanner processor is incorporated into the system to provide flexibility in the operation of the AMPR imager. The scanner processor is based on the Motorola MC68HC705C8 micro-controller. This single chip micro handles system timing, scanner control, encoder feedback, data interface, and system diagnostics. Appendix A provides the complete software source code for the AMPR scanner processor. Table 5 shows the various scanner modes that can be selected by turning a thumbwheel switch located in the AMPR power and signal distribution box. Table 6 shows the different menu options available when operating in mode 0. The interactive nature of mode 0 requires that an RS-232 device be attached to the AMPR serial (DCE) port.



Note: Above start & stop scan positions do not provide totally unobstructed view of scene below aircraft.

Figure 4. Scan / Calibration Geometry for AMPR Instrument.

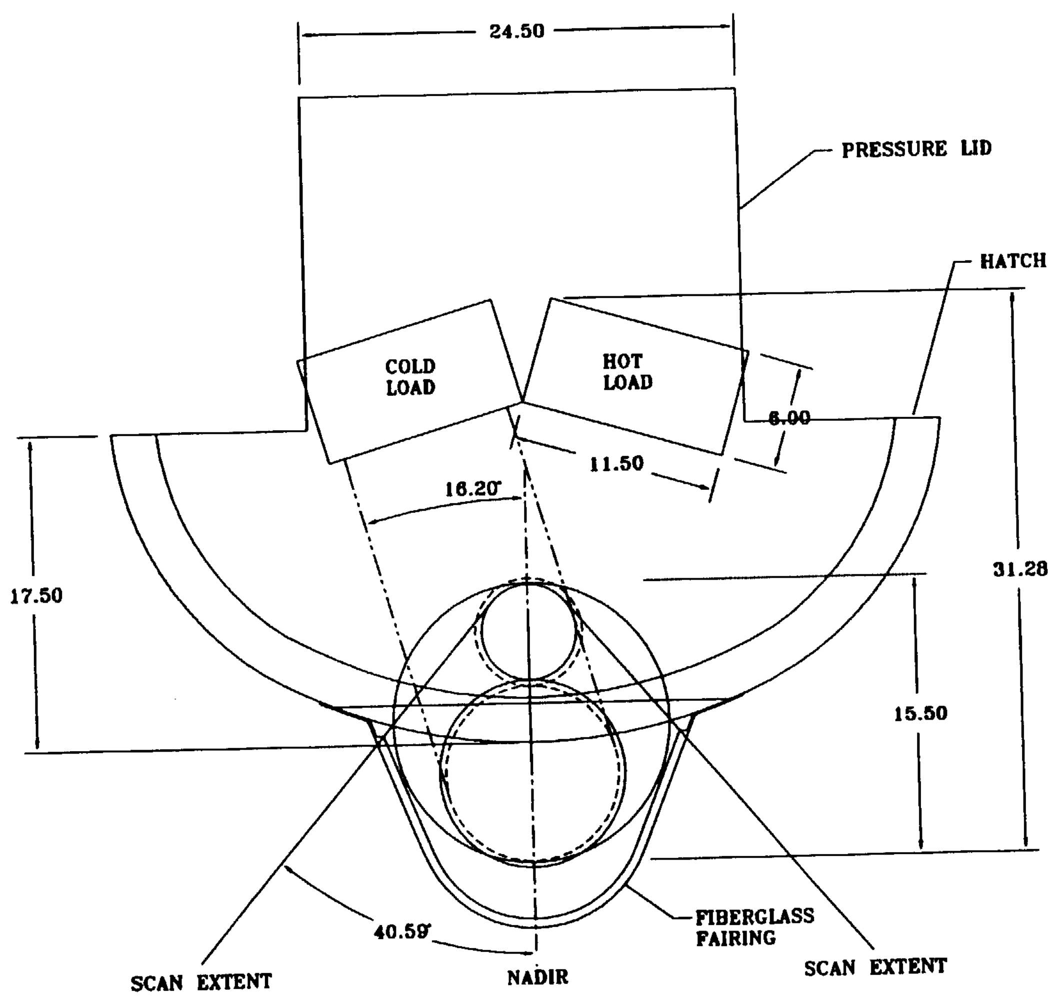


Figure 5. AMPR/HI-CAMP Hatch End View With Calibration Loads Above

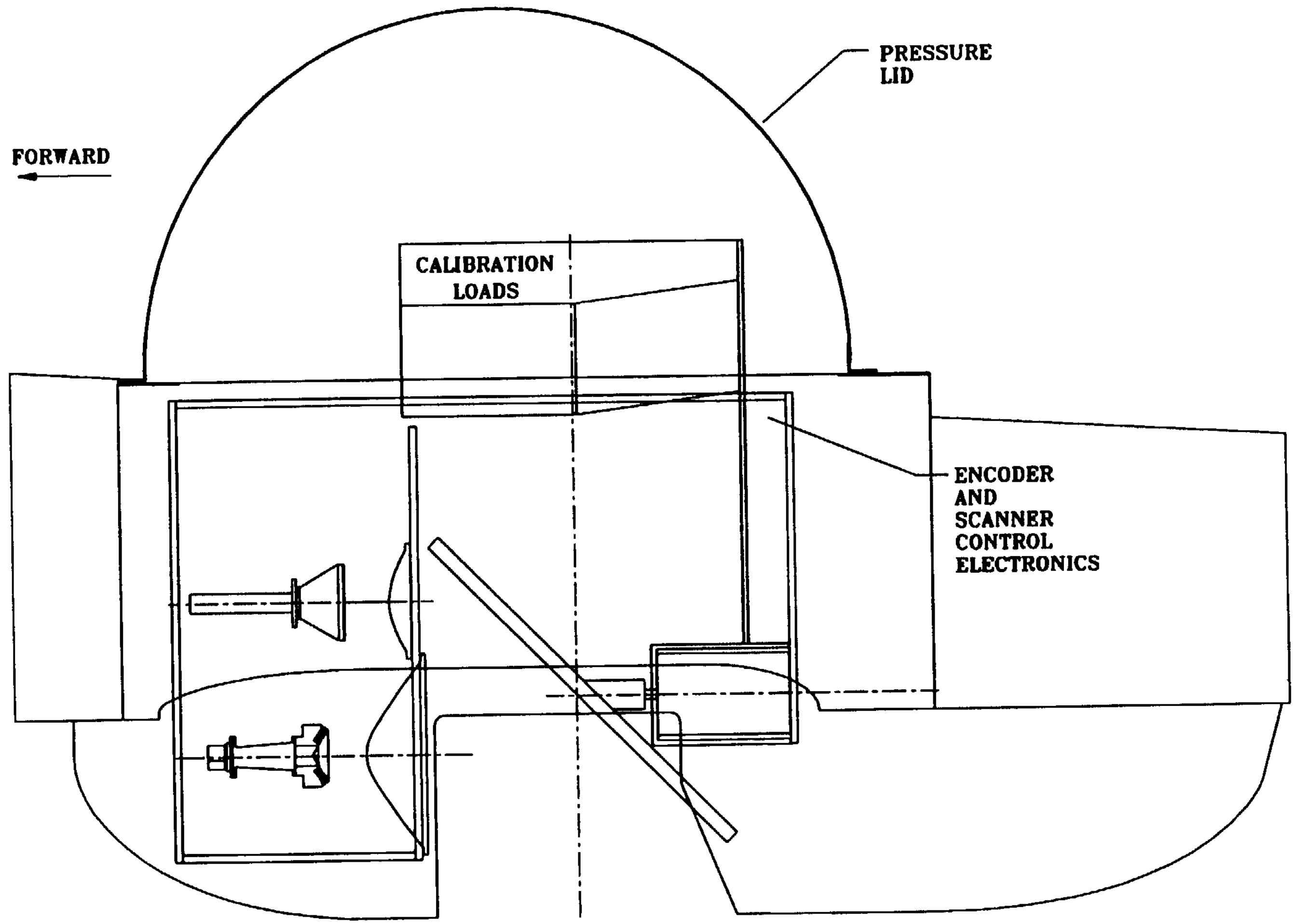


Figure 6. AMPR Radiometer Section Looking to Starboard

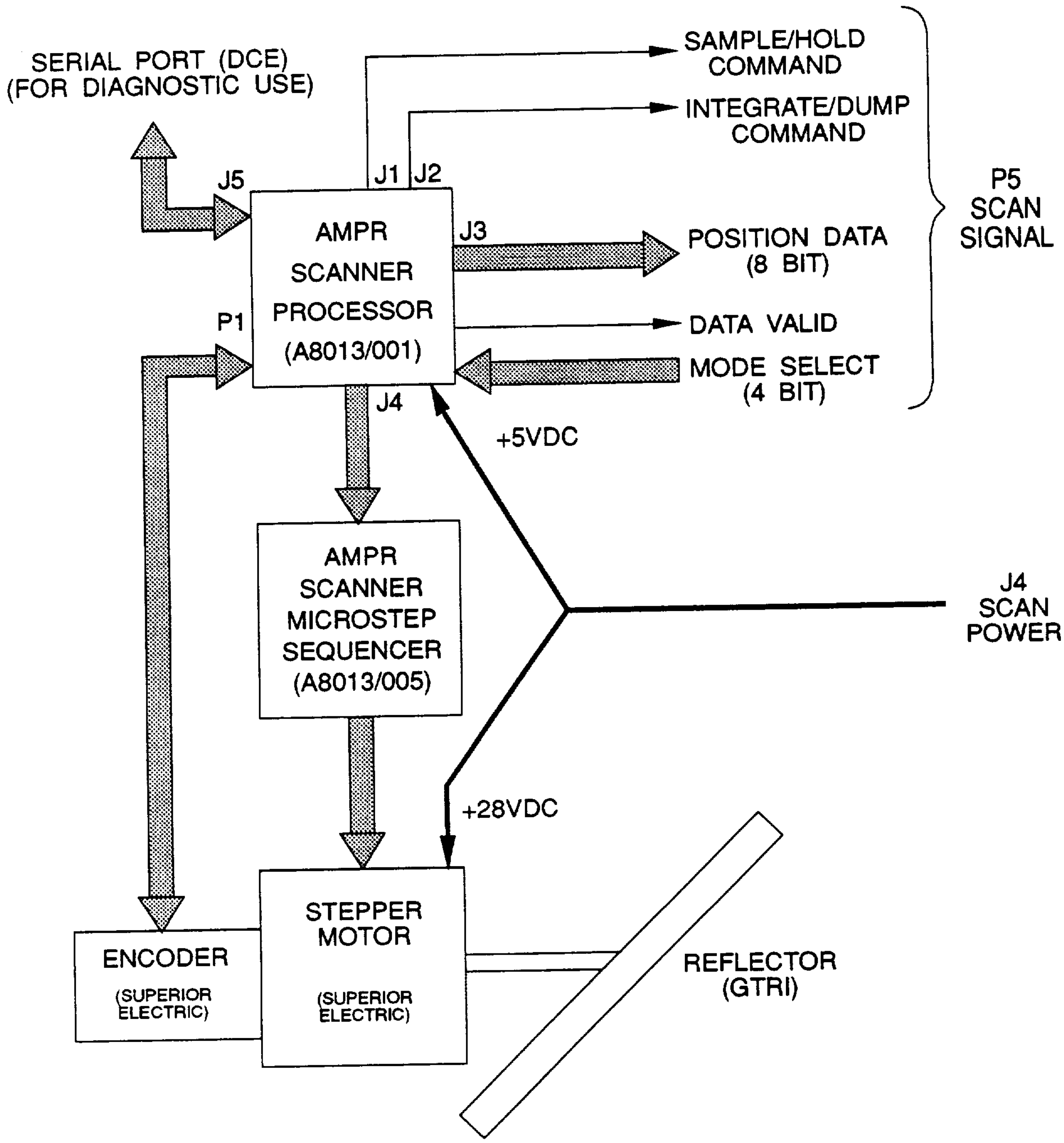


FIGURE 7. SCANNER SYSTEM BLOCK DIAGRAM

TABLE 5. DESCRIPTION OF SCANNER PROCESSOR MODES

Mode Number	Description
0	Monitor mode
1	Scan mode· 4 scans/calibrate, CCW retrace
2	Scan mode; 6 scans/calibrate, CCW retrace
3	Scan mode; 8 scans/calibrate, CCW retrace
4	Scan mode; 10 scans/calibrate, CCW retrace
5	Scan mode; 12 scans/calibrate, CCW retrace
6	Scan mode; 14 scans/calibrate, CCW retrace
7	Scan mode; 16 scans/calibrate, CCW retrace
8	Scan mode; 4 scans/calibrate, CW retrace
9	Scan mode; 6 scans/calibrate, CW retrace
A	Scan mode; 8 scans/calibrate, CW retrace
B	Scan mode; 10 scans/calibrate, CW retrace
C	Take data in stare mode
D	1 kHz on port "A" bit 7 of microcontroller
E	Stepper motor test diagnostic
F	Port "A" test mode

TABLE 6. DESCRIPTION OF MODE 0 MENU OPTIONS

Mode 0 Menu Option	Description
A	Perform one "n" scans/calibrate cycle
C	Move scan reflector to cold load
D	Toggle motor direction bit (CW/CCW)
E	Read encoder data continuously
G	Get data for current scanner location
H	Move scan reflector to hot load
I	Toggle integrate/dump bit (dump/integrate)
L	List AMPR status
M	Set exit mode: 0-F (hex)
N	Set number (n) of scans per calibrate: 0-F (hex)
P	Take step; report position
R	Return to encoder index position
S	Toggle sample/hold bit (sample/hold)
V	Toggle data valid bit (low/high)
W	Toggle windings bit (on/off)
X	Exit to next mode
?	Monitor command menu

CALIBRATION SYSTEM

The AMPR calibration loads are required to operate over the frequency range of 10.7 to 85.5 GHz to insure absolute temperature data at the four distinct AMPR RF channels. The lowest frequency channel at 10.7 GHz requires a highly emissive RF load with sufficient depth to insure that the longer wavelength (28 mm or 1.1 in.) signal is fully absorbed by the near perfect black body load. At the other extreme, the highest frequency channel at 85.5 GHz requires that the load material be conductive enough to insure that the physical temperature is approximately uniform over the full depth of the load material.

The material for the calibration loads was obtained from Emerson & Cuming under the designation "Eccosorb UHP-2-NRC" with a specified return loss exceeding 40 dB (ϵ greater than 0.9999) up to a maximum frequency of 93 GHz. Under this condition the calibration load radiometric temperature (T_R) is given by:

$$T_R = (1 - \epsilon)\, T_B + \epsilon\, T_p$$

for T_B = background temperature which illuminates load

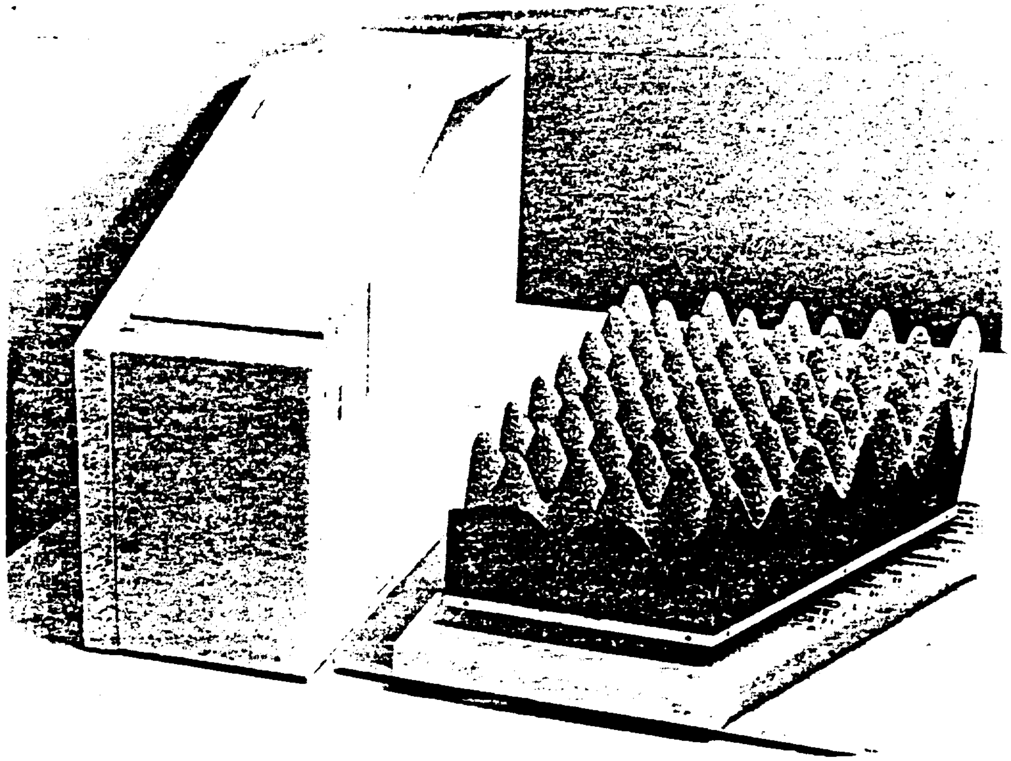
and T_p = calibration load physical temperature.

Assuming that the minimum observed temperature (T_B) is 10K and the maximum physical load temperature (T_p) is 350K for the hot load, then

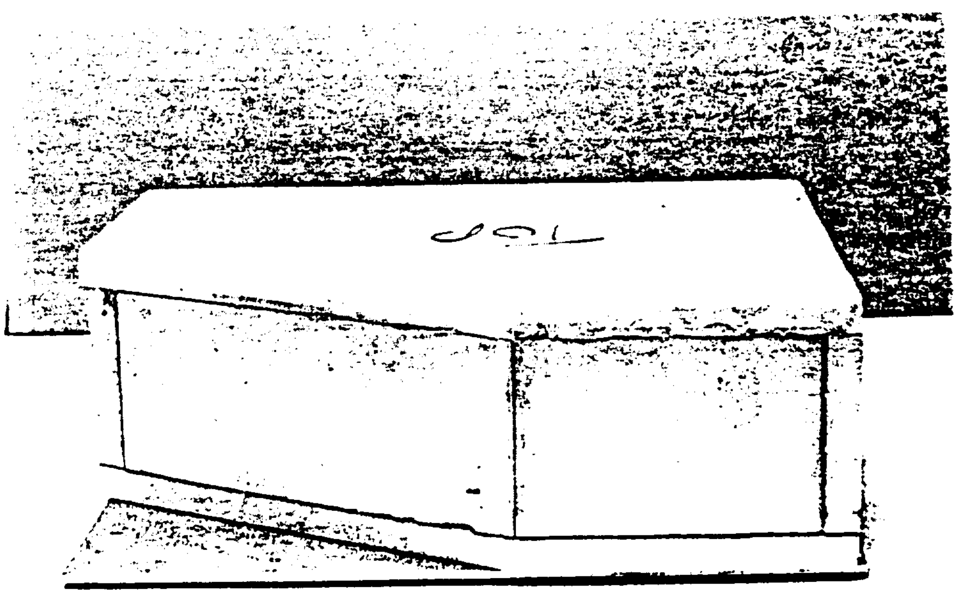
$$\begin{aligned} T_R &= (0.0001)\,(10K) + (0.9999)\,(350K) \\ &= 349.966K. \end{aligned}$$

Therefore the calibration load radiometric temperature (T_R) very nearly equals the physical temperature (T_P) which implies a nearly perfect black body calibration load.

Figure 8 is a photograph of the calibration loads without the low loss insulating foam cover (view a) and with the foam cover installed (view b). The hot load temperature of 320K is implemented using dc heater strips mounted on the



(a) Foam Cover Removed



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(b) Foam Cover Installed

Figure 8. AMPR Calibration Load

metal back plate used to support the RF absorber material. The cold load is implemented using an inlet hose connected to outside air (about 233K at 20 km altitude). A ram air scoop is provided on the ER-2 fairing for connection to the cold load. The RF loss of the insulating cover used on each load is specified to be less than 0.1 dB over the full frequency range.

Figure 9 shows the calibration system block diagram. Monitor circuitry measures thermistors mounted in both the hot and cold calibration loads. The seven thermistors mounted in the hot load (Model # 44201) are accurate to within ± .15°C over the range from 0° to 100°C while the seven thermistors mounted in the cold load (Model # 44212) are accurate to within ± .1°C over the range from -50°C to 50°C. Thermistor placement within each load is shown in Figures 10 and 11. Figure 10 also shows the placement of the two dc heater strips. The hot load temperature is controlled by using one of the hot load thermistors to feed back and compare to a reference set point. A pulse width modulation technique is then employed based on this temperature comparison to drive current through the dc heaters. As shown in Figure 9, cold and hot load temperature multiplexers take the conditioned thermistor temperatures and make them available based on the channel select lines input from the MSFC data acquisition system. The channel designations are given in Table 7.

Figure 12 illustrates the absolute temperature accuracy of the AMPR using the hot and cold calibration loads described above. A hot load temperature of +37°C (310K) and a cold load temperature of -43°C (230K) are used in the curves of Figure 12. The curve with a ΔT_{min} value of 0.4K represents the 19.35 GHz AMPR data channel and the curve with a ΔT_{min} value of 0.2K represents the 37.10 GHz AMPR data channel. For example, if the radiometer unknown temperature is 100K, then the AMPR measurement will be accurate within ± 2.1K at 19.35 GHz and within ± 1.3K at 37.1 GHz. The 10.7 GHz and 85.5 GHz AMPR data channels fall in between these two curves. Table 8 summarizes the AMPR absolute temperature accuracy range for an unknown scene temperature.

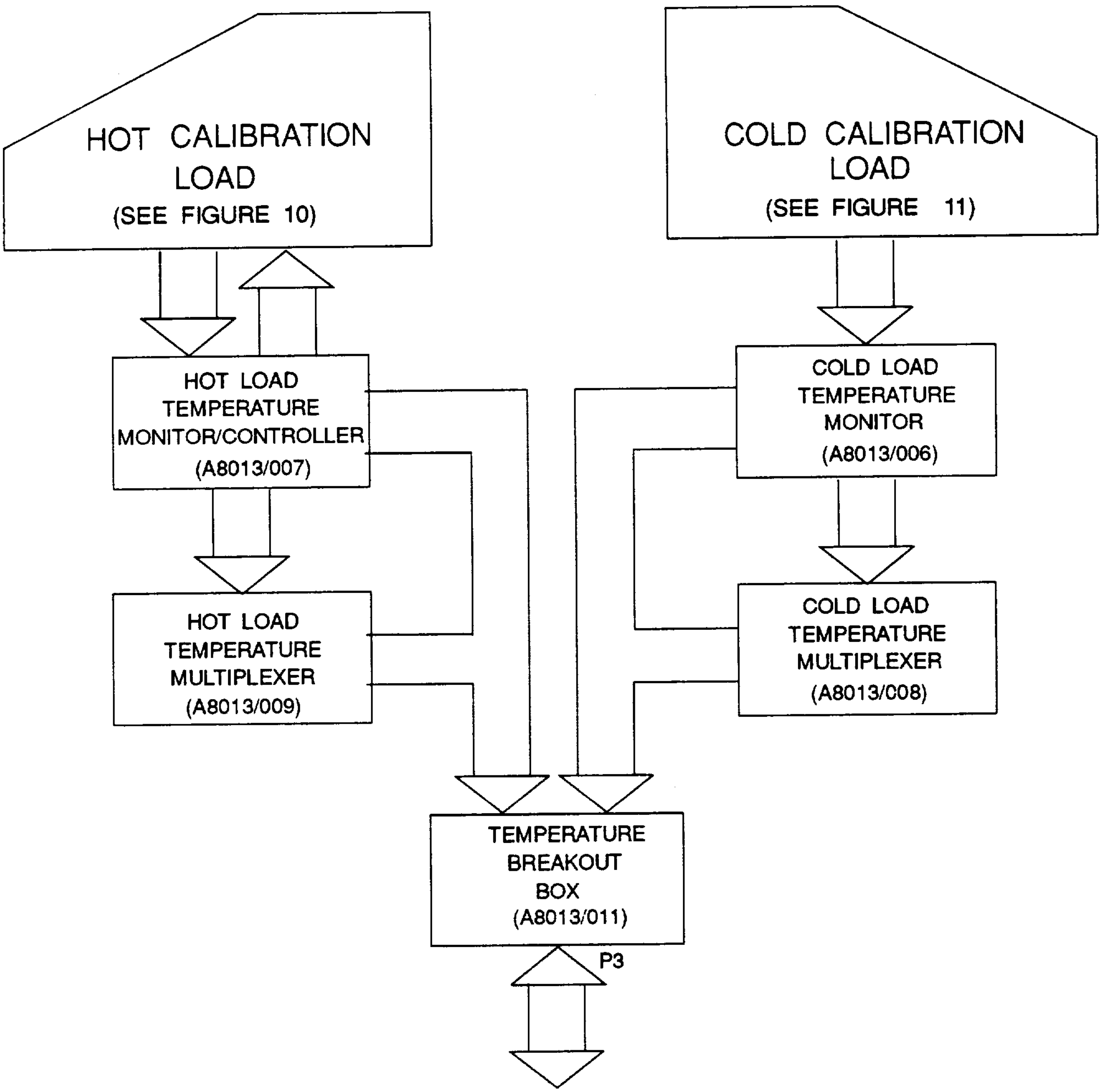


FIGURE 9. CALIBRATION SYSTEM BLOCK DIAGRAM

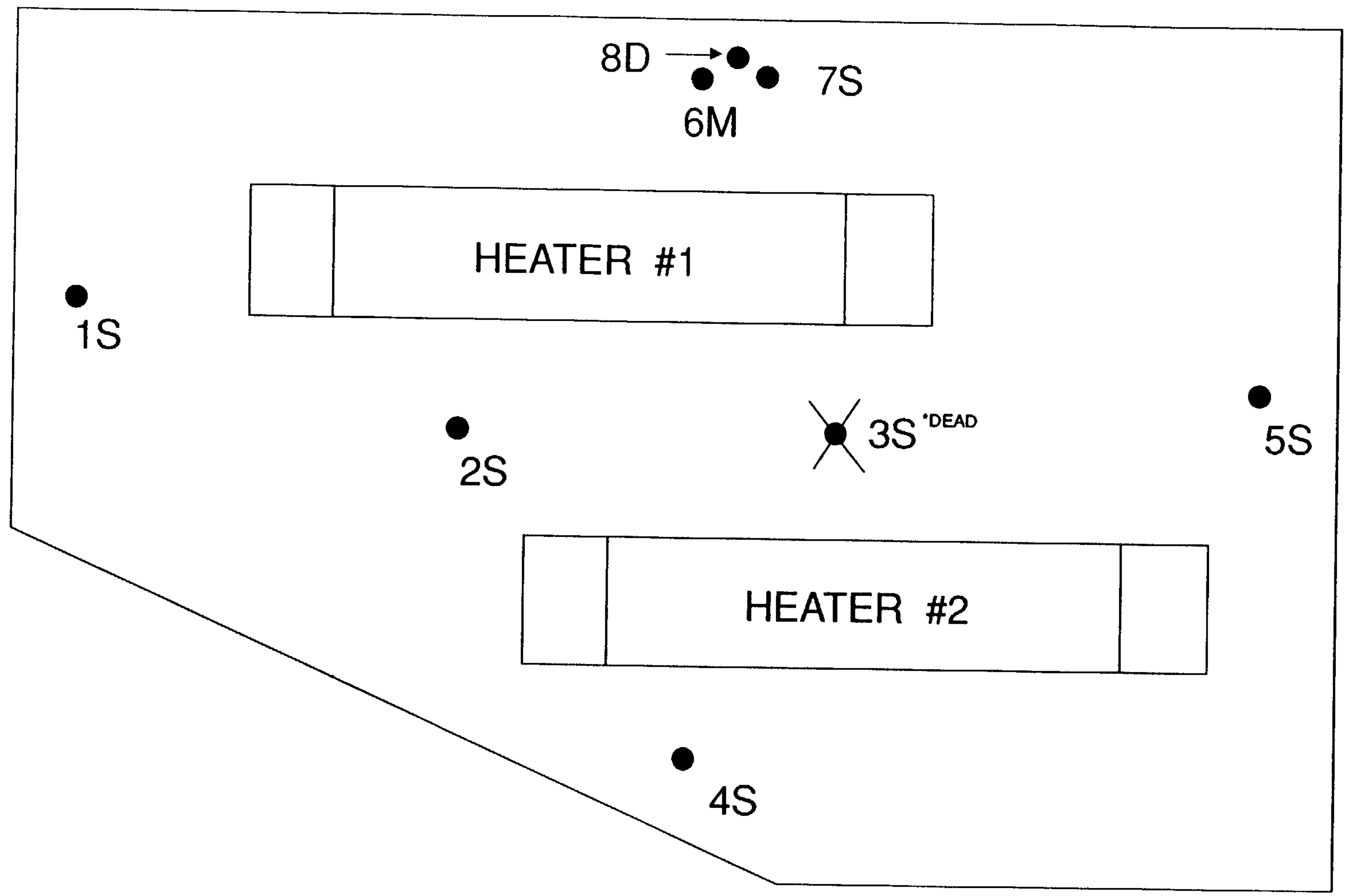


FIGURE 10. HOT CALIBRATION LOAD (BOTTOM VIEW)
Thermistor locations 1-8 as shown
Heater strips as shown

S- shallow

M- medium

D- deep

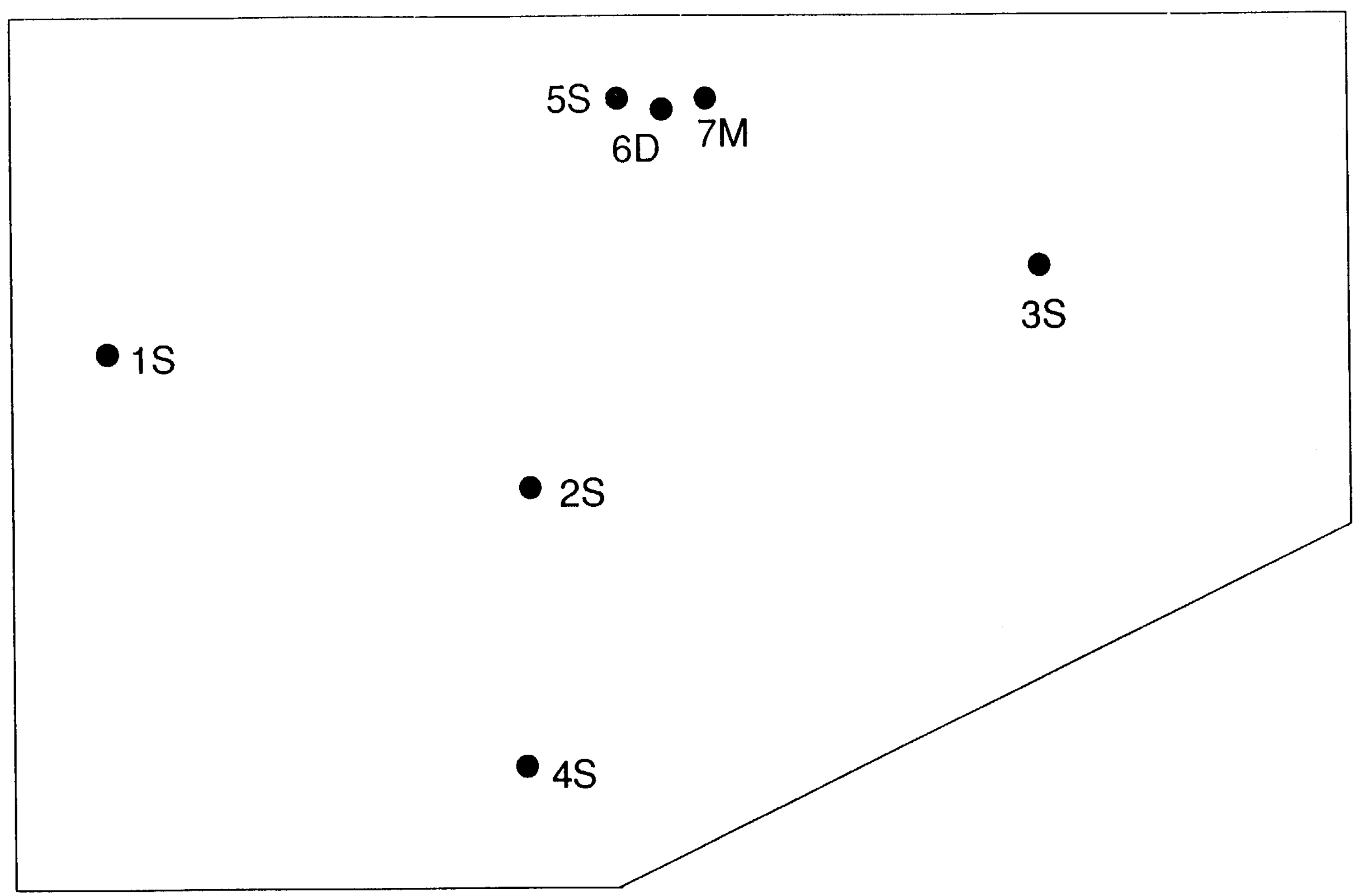


FIGURE 11. COLD CALIBRATION LOAD (BOTTOM VIEW)
Thermistor locations 1-7 as shown

S- shallow
M- medium
D- deep

TABLE 7. TEMPERATURE MULTIPLEXER CHANNEL DESIGNATIONS

Channel No.	Hot Load	Cold Load
0(0000)	Thermistor #1	Thermistor #1
1(0001)	Thermistor #2	Thermistor #2
2(0010)	Thermistor #4	Thermistor #3
3(0011)	Thermistor #5	Thermistor #4
4(0100)	Thermistor #6	Thermistor #5
5(0101)	Thermistor #7	Thermistor #6
6(0110)	Thermistor #8	Thermistor #7
7(0111)	Not used	Not used
8(1000)	Not used	Not used
9(1001)	Not used	Not used
10(1010)	Not used	Not used
11(1011)	Not used	Not used

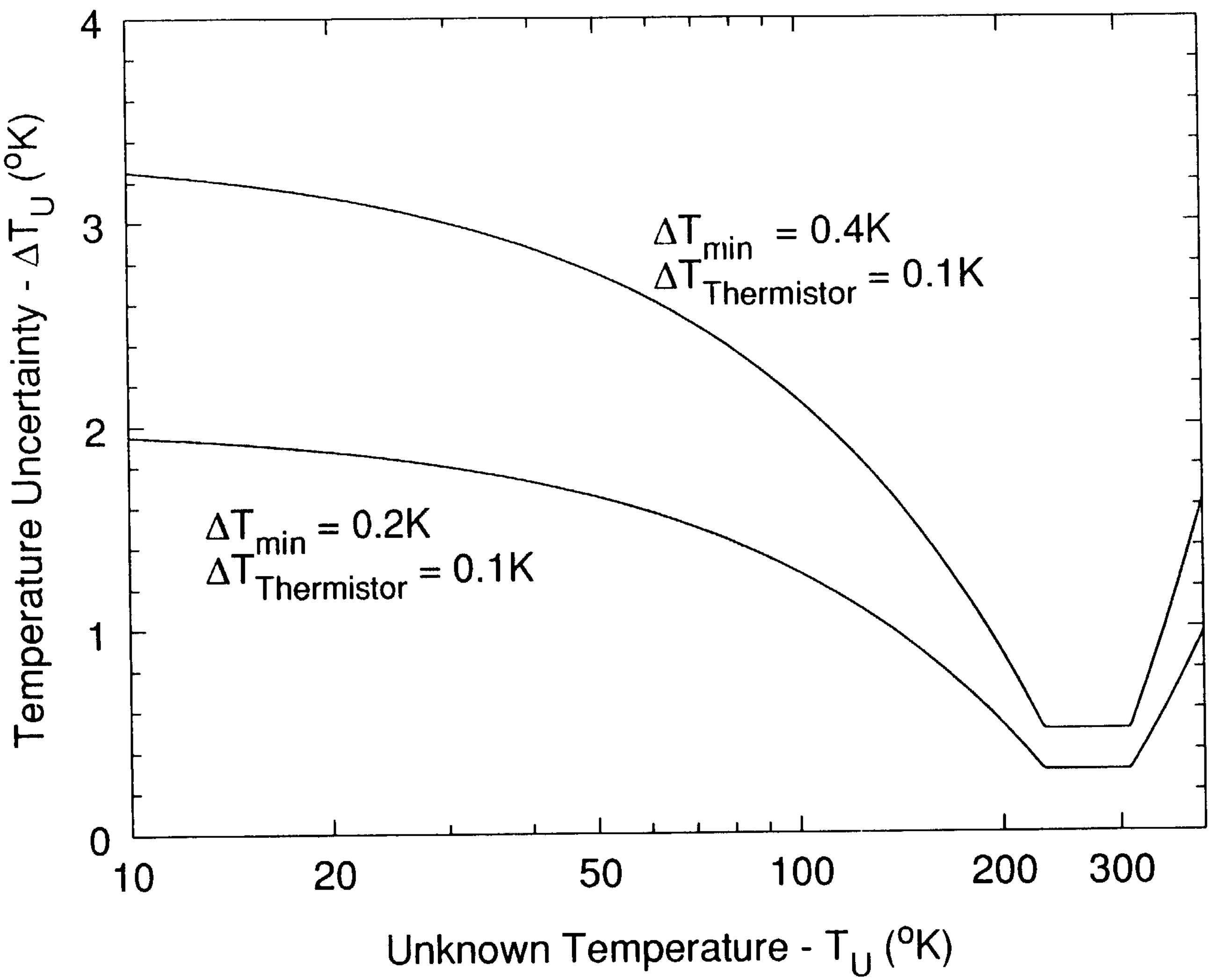


Figure 12. AMPR Absolute Temperature Inaccuracy (ΔT_U) Goals For Hot Calibration Load (T_H) of 310K And Cold Calibration Load (T_C) of 230K

TABLE 8. AMPR ABSOLUTE TEMPERATURE INACCURACY (ΔT_u) PERFORMANCE SUMMARY FOR UNKNOWN SCENE TEMPERATURE (T_u)

T_u (K)	$\pm\ \Delta T_u$ (K) For AMPR Channel	
	19.35 GHz	37.10 GHz
10	3.3	2.0
20	3.1	1.9
40	2.9	1.7
80	2.4	1.4
100	2.1	1.3
140	1.6	1.0
200	0.9	0.5
230 (T_{COLD})	0.5	0.3
300	0.5	0.3
310 (T_{HOT})	0.5	0.3
340	0.9	0.5
400	1.6	1.0

Note 1. 10.7 and 85.5 GHz channels fall in between above range for each T_u value.

Note 2. Example: At T_u = 100K,
$\Delta T_u = \pm$ 1.7K for 10.7 GHz channel
and $\Delta T_u = \pm$ 1.4K for 85.5 GHz channel.

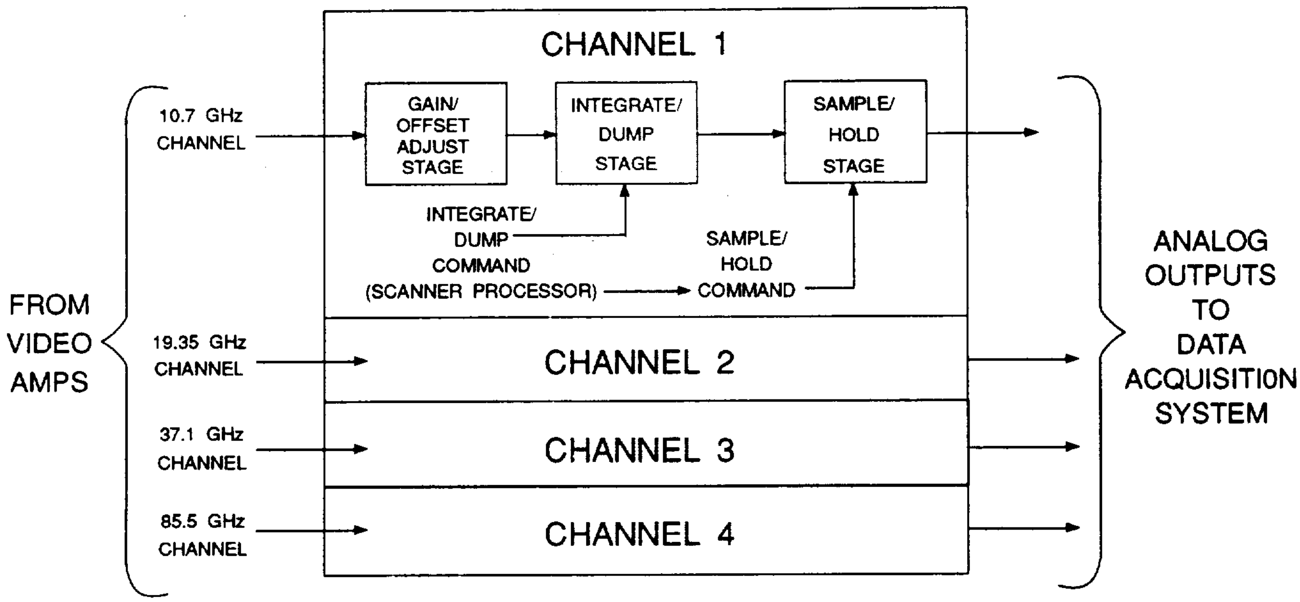
VIDEO PROCESSOR SYSTEM

The AMPR video processor system consists of the post detection circuitry and the interface circuitry to the data acquisition system (provided by MSFC). The primary design criteria as regards the interface circuitry was to insure that the AMPR operated as a stand-alone system. This design approach insured that AMPR does not depend on the data acquisition system for control or handshaking information that might affect a critical operation, such as the scanner timing. A secondary design goal for the interface system was insuring that the data transfer between AMPR and the data acquisition system would be simple and repeatable.

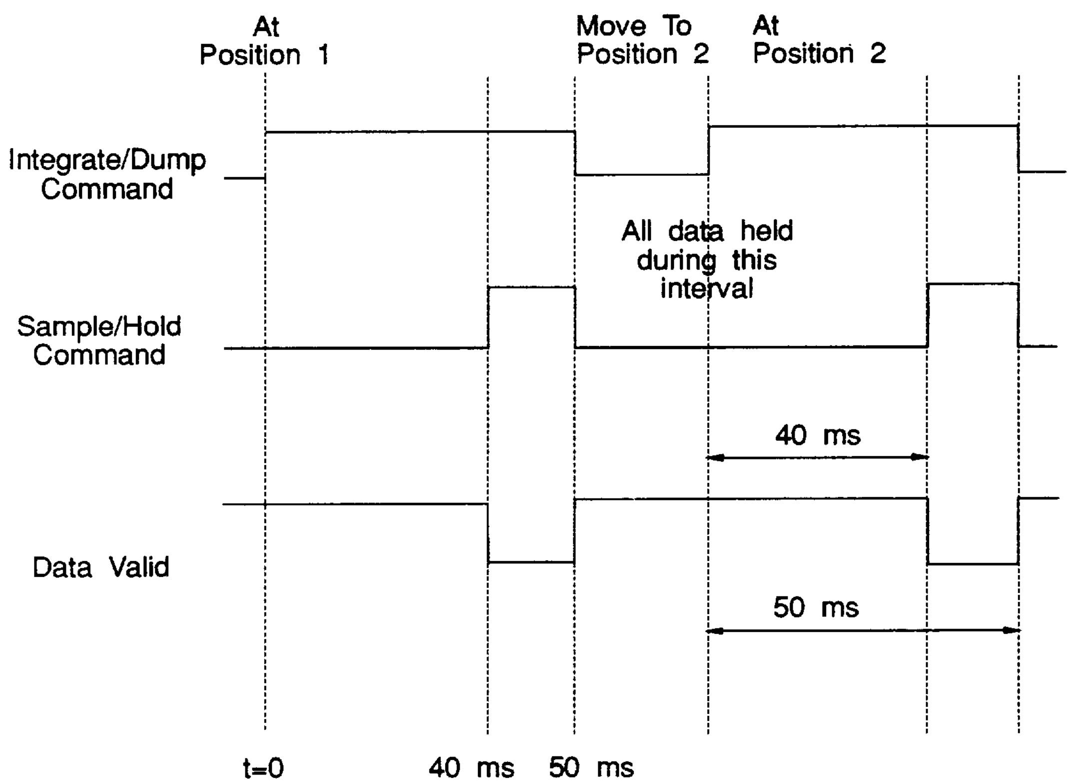
The post detection circuitry for the AMPR consists of the video amplifier which amplifies the radiometer's square law detector output, the integrate and dump circuit which integrates the video amplifier output, and the sample and hold circuit which maintains the data output until the data acquisition system samples the AMPR data. The AMPR interface provides a data valid signal which alerts the data acquisition system that the analog data is valid and ready for sampling. Figure 13 is the AMPR video processor block diagram (a) and the timing diagram (b) for the integrate/dump, sample/hold, and the data valid signals.

MECHANICAL PACKAGING

The AMPR system consists of two packages, i.e. the radiometer unit and the power supply unit. The radiometer package includes the scanner, calibration loads, RF front-end, and video processing subsystems. The power supply unit contains all the power supplies required to operate the radiometer, the power conditioning interface to the aircraft power distribution unit, and the interface circuitry to the data acquisition system. Figure 14 is a photograph of the power supply unit package designed to adapt to the existing aircraft rack located in the ER-2 upper Q-Bay compartment. Table 9 indicates the system power supply designations for each unit supply used in the AMPR. The seven multi-pin connectors are the connections between the power supply unit and the radiometer package (four cables), the data acquisition system (two cables), and the aircraft power distribution unit (one cable). A removable cover is shown in the photograph and is used to



(a) Block Diagram



(b) Timing Diagram

FIGURE 13. AMPR VIDEO PROCESSOR SYSTEM

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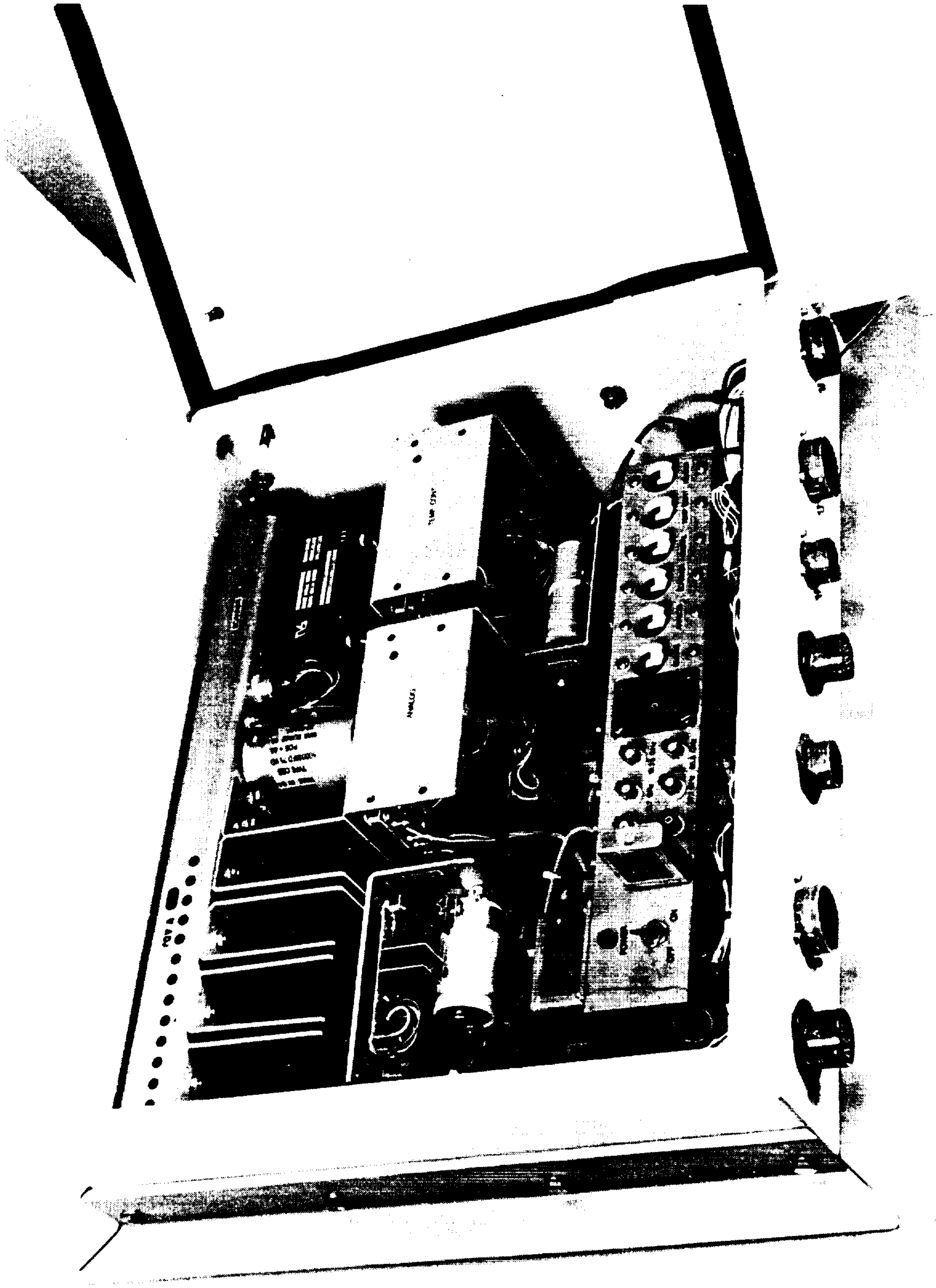

Figure 14. AMPR System Power Supply Package.

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TABLE 9. POWER SUPPLY MONITOR MULTIPLEXER CHANNEL DESIGNATIONS

Channel No.	Mux A Output	Mux B Output
0(0000)	37.1 GHz bias (+4.0 V)	
1(0001)	85.5 GHz bias (+5.4 V)	
2(0010)	19.35 GHz bias (+7.0 V)	
3(0011)	Analog supply + (+10 V)	
4(0100)	Analog supply - (-10 V)	
5(0101)	Not used	
6(0110)	Not used	
7(0111)	Not used	
8(1000)		Digital supply + (+5V)
9(1001)		Scanner supply + (+9.3 V)
10(1010)		Temperature supply + (+10 V)
11(1011)		Temperature supply - (-10 V)
12(1100)		Not used
13(1101)		Not used
14(1110)		Not used
15(1111)		Not used

protect the internal power supplies during shipment and aircraft installation. The cover is removed during aircraft flights to reduce the internal temperature caused by heat generated by the power supplies.

Figure 15 is a photograph of the AMPR radiometer package as viewed from the RF front-end. View (a) depicts the radiometer with RF cover installed and view (b) shows the RF cover removed. The cover is lined with RF absorber material to improve system immunity to outside RF signal interference. Figure 16 is another view of the AMPR package as seen from the scanner end of the radiometer. This view depicts the elliptical reflector used to scan across the dual lens antenna. The hot and cold calibration loads are shown in the lower part of the photograph with low loss foam covers. View (a) shows the scanner cover installed while view (b) shows the cover removed.

AMPR TEST RESULTS

AMPR testing included subsystem, as well as, system tests following final assembly. Subsystem tests performed included: antenna pattern measurements on the 10.7 GHz antenna feedhorn/lens unit and the SSM/I multifrequency feedhorn/lens unit at the Georgia Tech Cobb County Facility antenna range; system noise figure measurements on each of the four receiver channels using the Y-factor test method; scanner routine tests using microstepping design techniques; and, temperature monitoring of the hot and cold calibration loads as well as temperature control of the hot load.

Figure 17 is an antenna range profile of the Georgia Tech Cobb County Facility which was used to perform AMPR antenna pattern measurements. This range facility offered minimum interference from ground reflections because of the natural terrain between the transmit and receive towers. Because of the rigidity of the towers and low ground reflection, accurate measurements of sidelobe levels, cross-polarization data, and mainbeam efficiency were obtained.

Antenna pattern measurements were performed at all frequencies for E-plane, H-plane, and diagonal plane cuts. These cuts represent the H polarization, V polarization, and 45° polarization plots for the antenna. When situated on the

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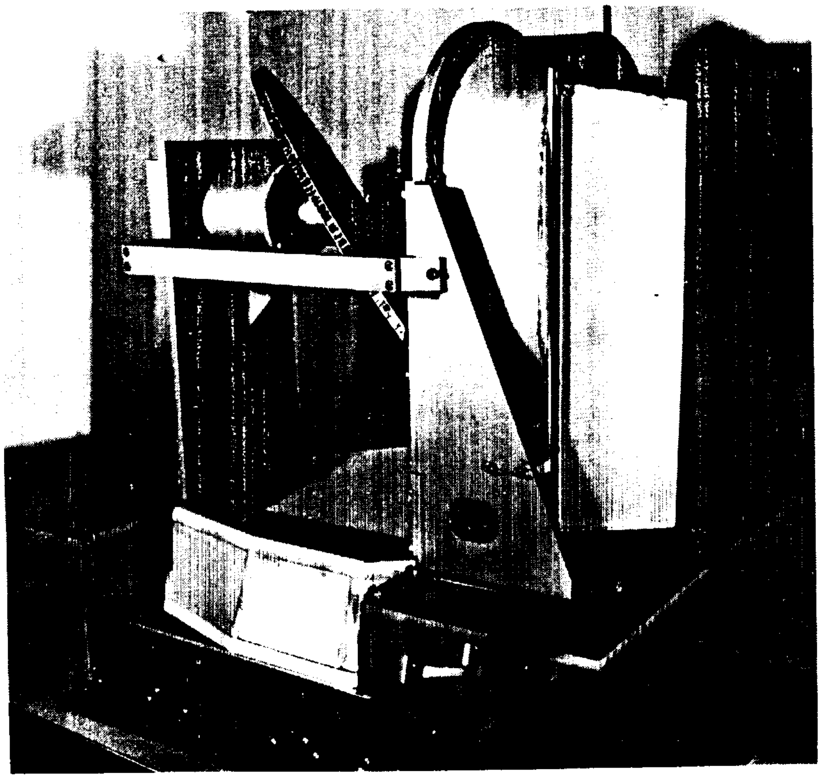
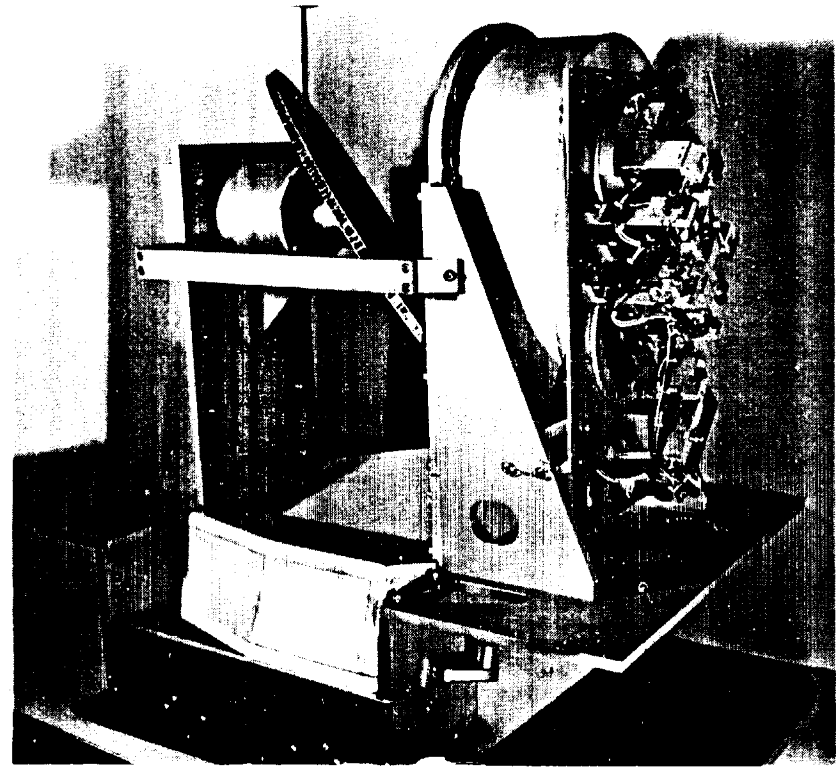


(a) RF Front-End Cover Installed



(b) RF Front-End Cover Removed

Figure 15. AMPR Package As Viewed From RF Front-End Assembly

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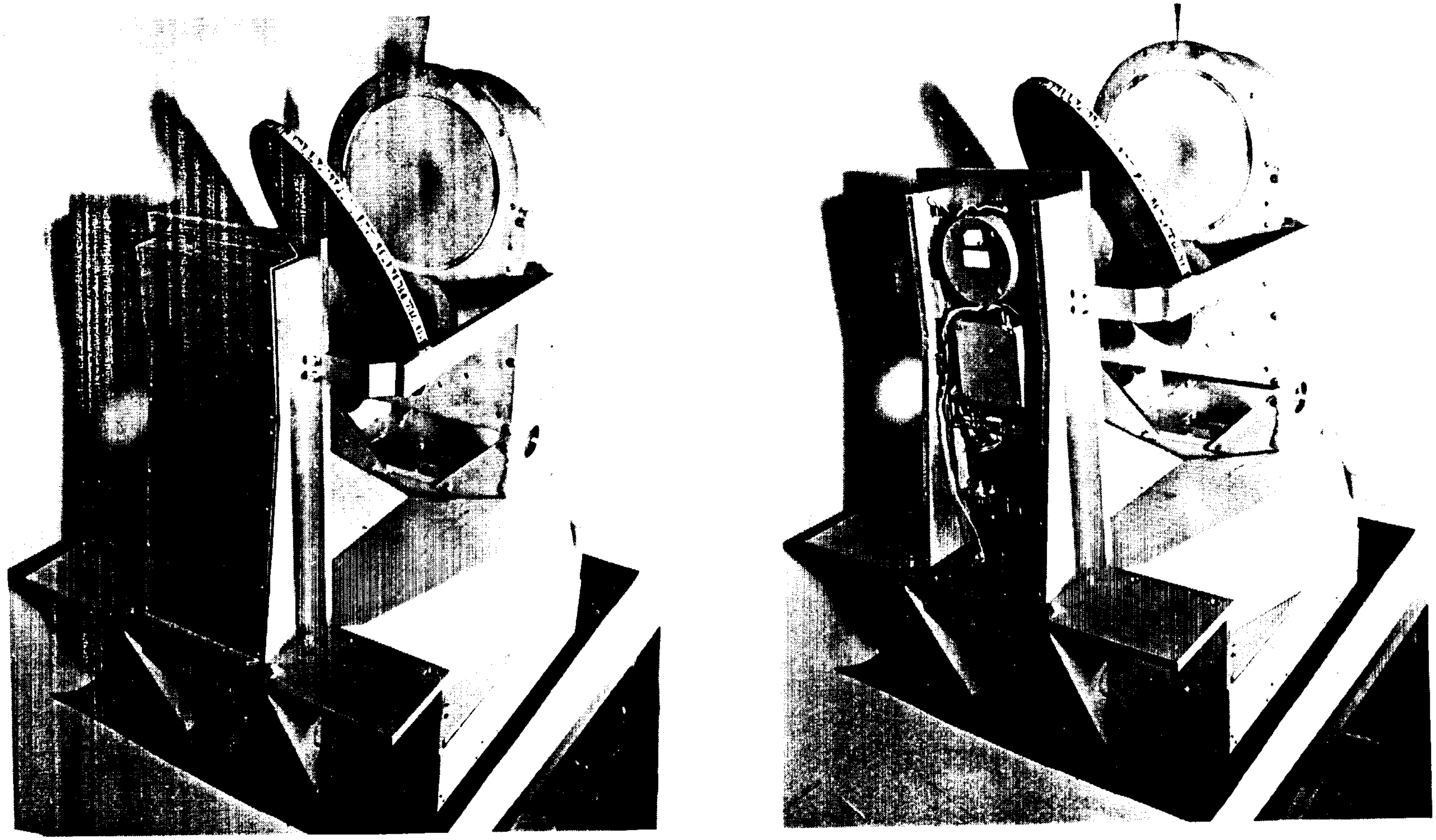


(a) Scanner Cover Installed

(b) Scanner Cover Removed

Figure 16. AMPR Package As Viewed From Scanner Assembly

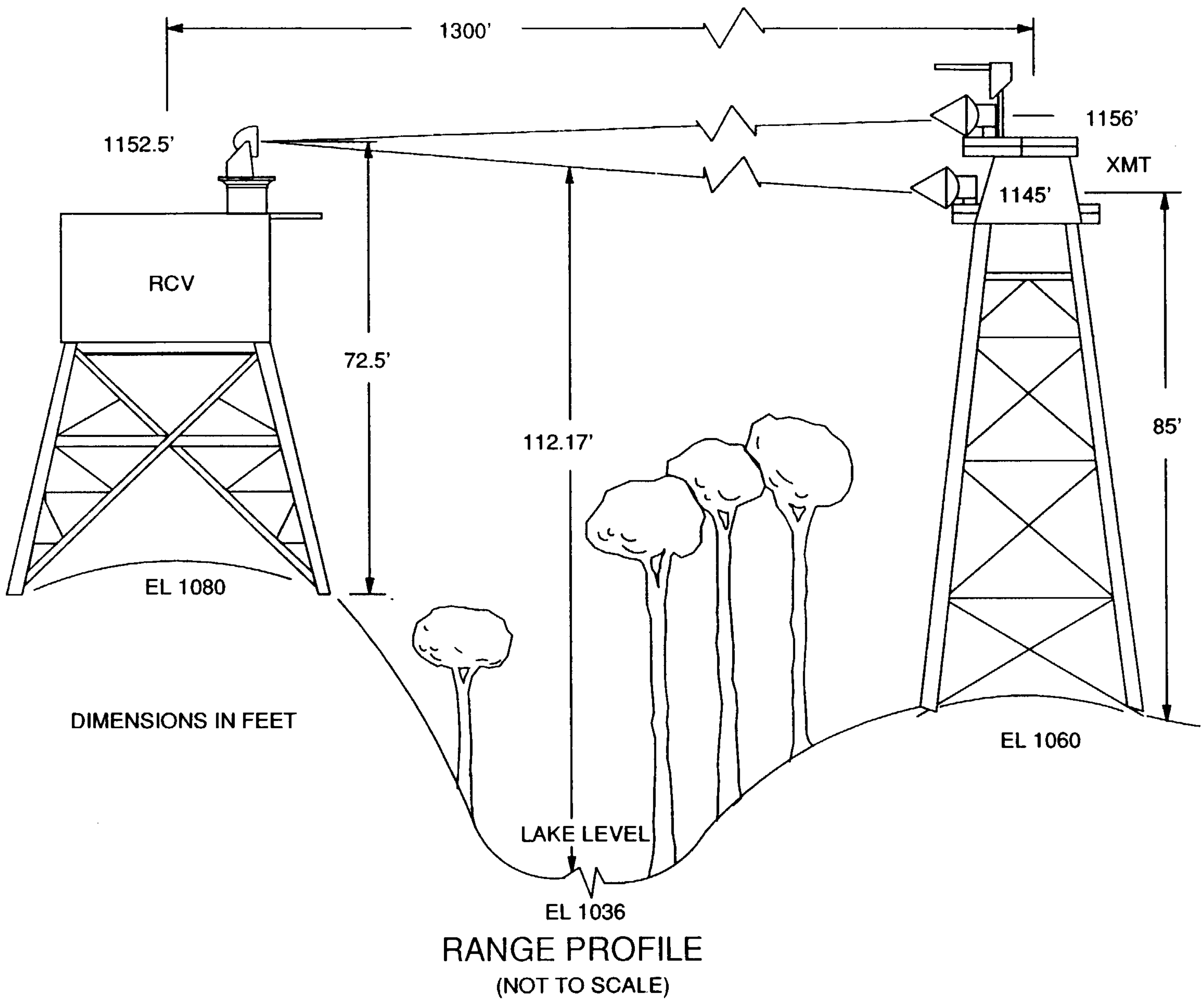


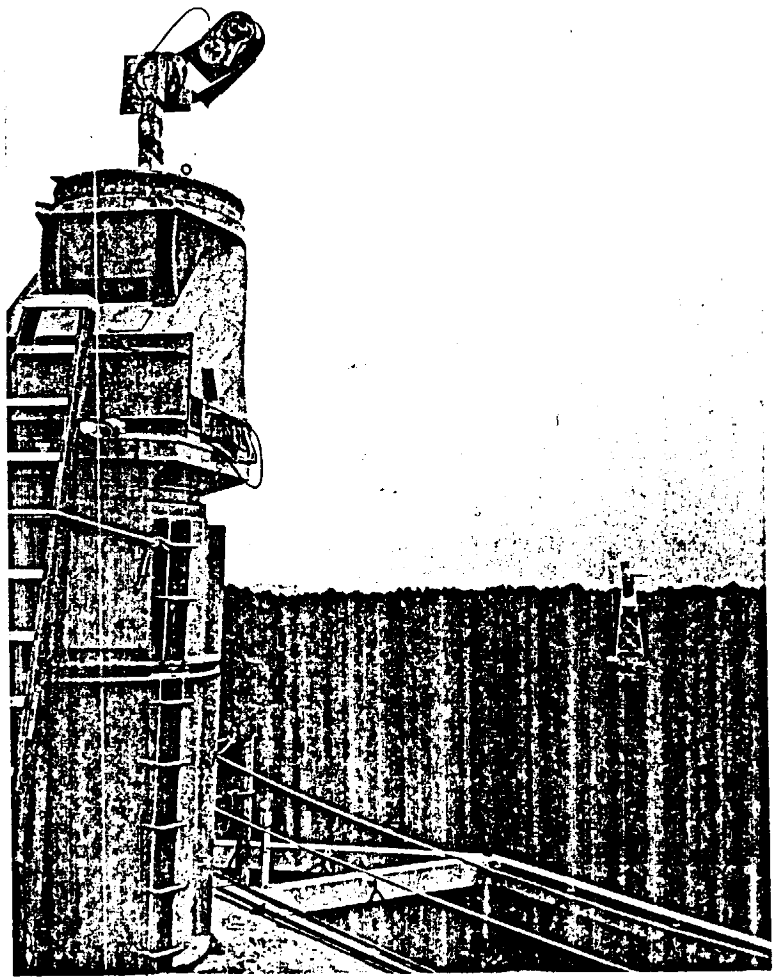
Figure 17. Georgia Tech Antenna Range Facility with Transmit (XMT) and Receive (RCV) Towers

ER-2 hatch, the H polarization is equivalent to looking out the right side of the aircraft, the V polarization is equivalent to looking out the left side of the aircraft, and the 45° or diagonal plane is equivalent to looking straight down (nadir view). Figure 18 provides a view of the AMPR antenna located on the range receive tower (shown in foreground) with the transmitter tower shown in background. View (a) represents the H polarization position while view (b) represents the V polarization positions. The 45° polarization position (not shown in Figure 18) would be between the H & V position, i.e. straight up and down on the receive tower.

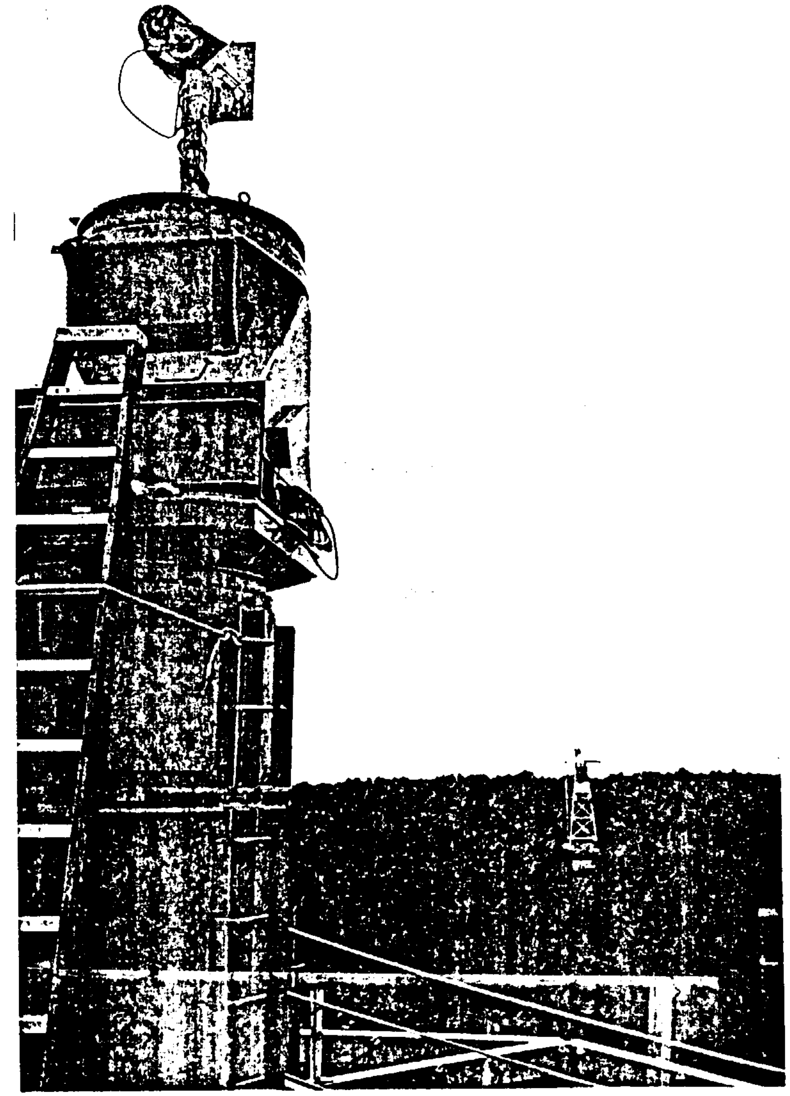
Table 10 summarizes the AMPR antenna subsystem performance based on the pattern measurements performed at the Cobb County Facility. The mainbeam efficiency represents the amount of power (in %) contained within the first null points. The sidelobe efficiency can be converted to sidelobe level, i.e. 0.20% efficiency means that the sidelobe level is -27 dB down from the peak power output. The cross polarization efficiency level of 0.40% means that the input cross-pol data is -24 dB down at the co-pol output port.

The 19.35, 37.10, and 85.5 GHz channels are generated using the multi-frequency feedhorn (MFFH) designed and built by Microwave Engineering Corporation. The AMPR MFFH is a replica of the antenna presently onboard the SSM/I spaceborne sensor.

The AMPR receiver sensitivity was measured for each of the four data channels using the Y-factor method. Figure 19 is a block diagram for the test set-up used to measure the noise figure (F_{dB}) for each channel. The test method consists of measuring the video output of each channel under two conditions, i.e. viewing an ambient load (290K) and viewing a liquid nitrogen load (100K). The F_{dB} value is given by:



(a) AMPR Positioned for H Polarization
(Right Side of Aircraft)



(b) AMPR Positioned for V Polarization
(Left Side of Aircraft)

Figure 18. AMPR Antenna Subsystem During Pattern Measurements

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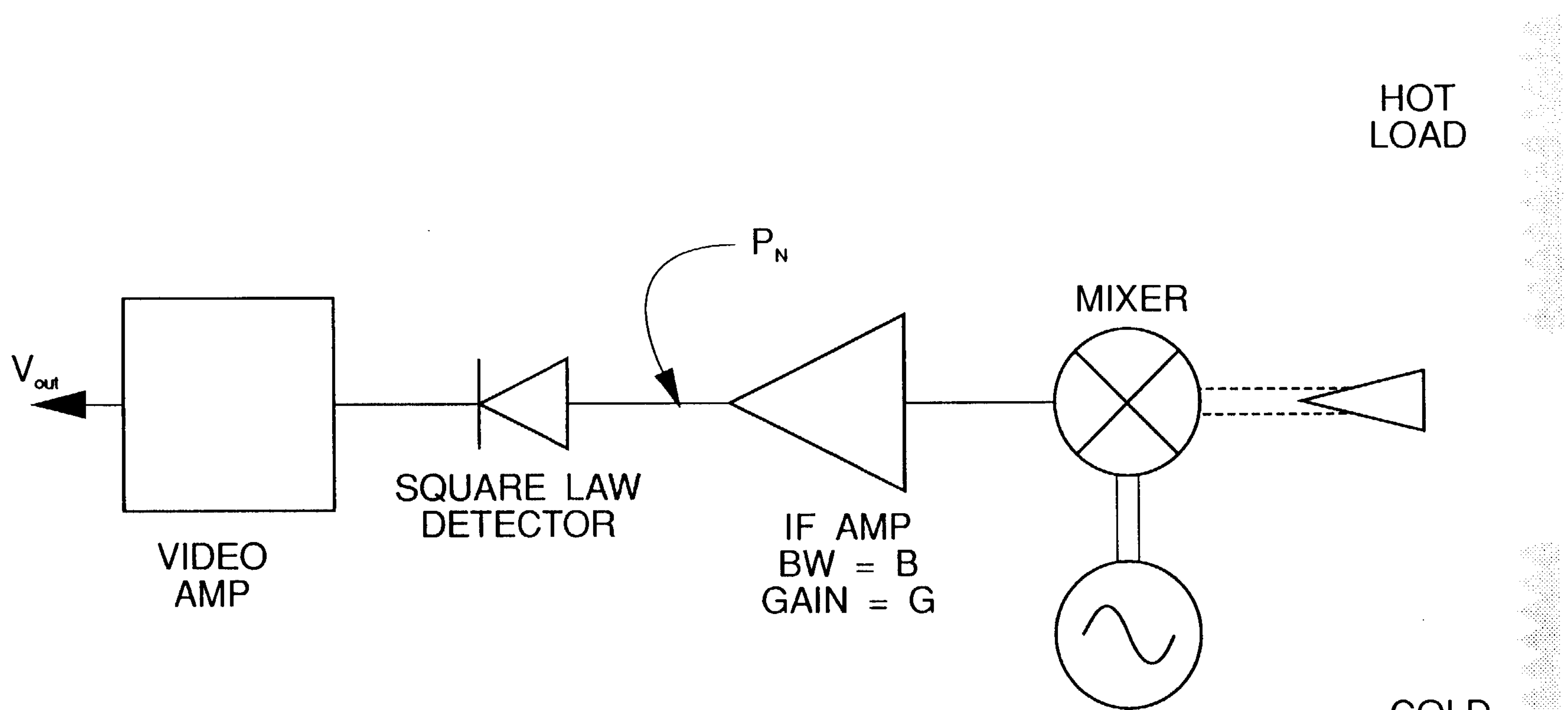
TABLE 10. AMPR ANTENNA PERFORMANCE LEVELS

CH (GHz)	Antenna Sidelobe (%)	Cross Polarization (%)	Mainbeam Efficiency (%) (Note 1)
10.7	0.20	0.20	97.8
19.35	0.30	1.60	98.7
37.0	0.20	0.40	98.8
92.5 (Note 2)	5.70	1.40	93.2

Note 1. Mainbeam efficiency data represents average of E, H, and 45° planes at each frequency and each attenuation level.

Note 2. Test equipment malfunctioning at 85.5 GHz caused increase in operating frequency to 92.5 GHz.



NOTE: $$Y = \frac{P_N(HOT)}{P_N(COLD)} = \frac{k(T_{SYS} + T_{HOT})BG}{k(T_{SYS} + T_{COLD})BG} = \frac{T_{SYS} + T_{HOT}}{T_{SYS} + T_{COLD}}$$

FIGURE 19. Y-Factor Method for Measuring System Noise Figure.

$$F_{dB} = 10 \log \left(\frac{V_{HOT}}{V_{HOT} - V_{COLD}} \right) - 1.8 \text{ dB}$$

for T_{HOT} = 290K and T_{COLD} = 100K.

The measurements were performed in order to determine the temperature sensitivity of each AMPR channel. Table 11 summarizes the ΔT_{min} values for each channel based on the noise figure data. The sensitivity values are based on a system gain variation ($\Delta G/G$) of 0.01% minimum to 0.05% maximum. In either case, the AMPR temperature sensitivities are less than 1.0K for all four data channels as required per NASA's specifications. Appendix B is a set of schematics for the electronic modules used in the AMPR system. Appendix C is a set of data sheets for vendor supplied items used in the AMPR. This appendix also includes a list of critical items recommended as spare parts for the AMPR.

The AMPR/Data Acquisition System is designed to be flown onboard the ER-2 research aircraft in the Q-bay compartment. The radiometer instrument is mounted in the HI-CAMP hatch which is located in the lower Q-bay section. The AMPR power supply package and the data acquisition system are each mounted in standard equipment racks located in the upper Q-bay section of the ER-2. Figure 20 is a cable diagram which shows the interconnection between the two AMPR packages, the aircraft input power cable (J1), and the two output cables (J6 and P7) to the MSFC data acquisition system. Cabling between the upper and lower Q-bay compartments is fed through the ER-2 bulkhead. Appendix D describes the AMPR cable interconnections including pin designations.

Figure 21 is a power schematic which shows the distribution of aircraft power to the AMPR radiometer. Power to the data acquisition system is routed through the AMPR power supplies package as shown. The ER-2 cockpit panel has two switches available for power/control of the AMPR system. The "AMPR ON" switch energizes the power relay internal to the AMPR power supply package. This results in aircraft power applied to the radiometer as indicated by the "AMPR

TABLE 11. AMPR ΔT_{min} MEASUREMENTS

Channel (GHz)	F_{sys} (F dB)	β (MHz)	ΔT_{min} (K) $\frac{\Delta G}{G} = 0.05\%$	$\frac{\Delta G}{G} = 0.01\%$
10.7	2.042 (3.1)	100	0.40	0.27
19.35	3.548 (5.5)	240	0.59	0.31
37.1	3.388 (5.3)	900	0.51	0.18
85.5	3.631 (5.6)	1400	0.54	0.16

Note 1. $\Delta T_{min} = T_o F_{sys} \left[\frac{1}{\beta\tau} + \left(\frac{\Delta G}{G} \right)^2 \right]^{1/2}$, for T_o = 290K (ambient) and τ = 50 ms (integ. time)

Note 2. 0.01% $\leq \frac{\Delta G}{G} \leq$ 0.05%, for $\frac{\Delta G}{G}$ = nominal system gain variation

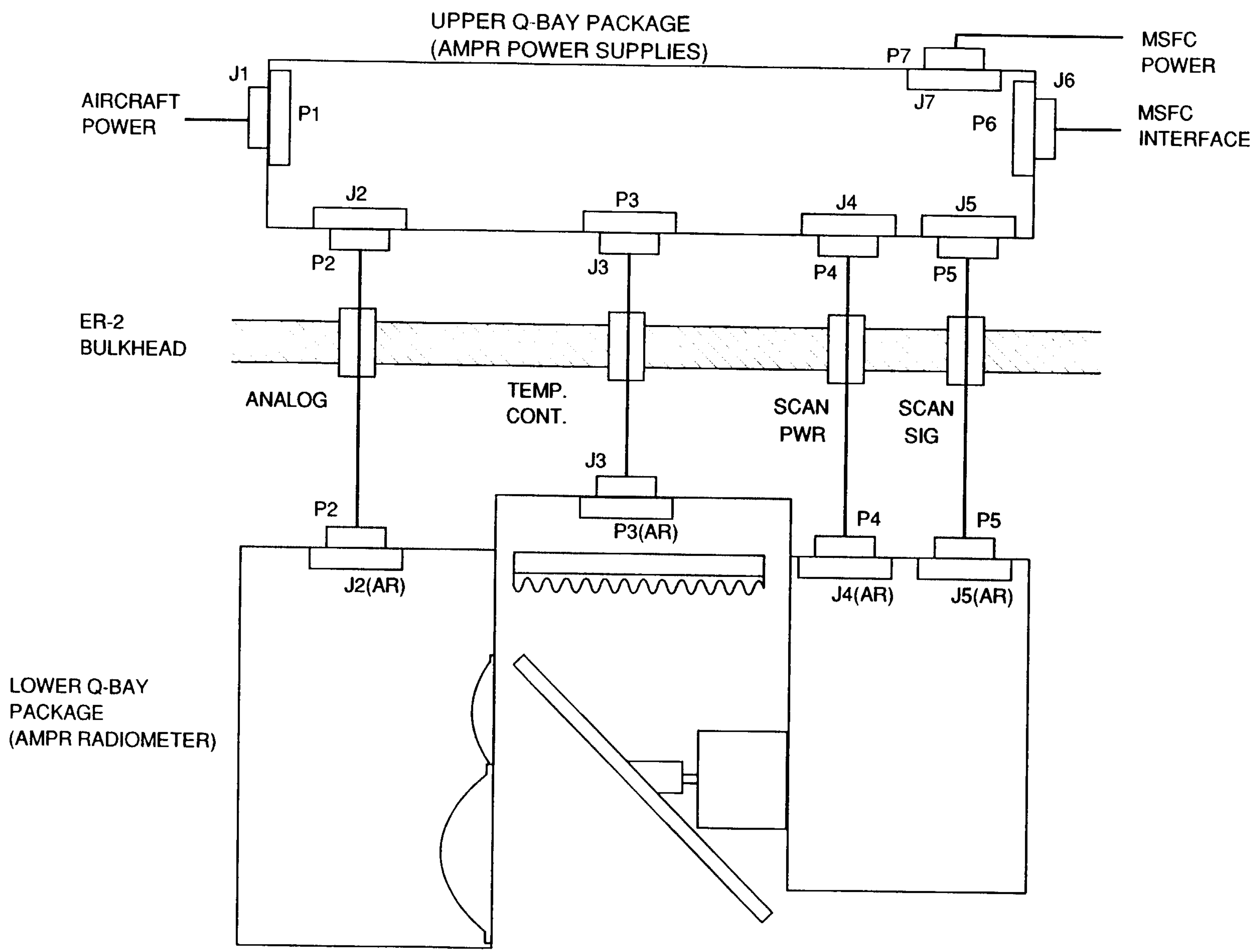


Figure 20. AMPR/ER-2 Cable Interconnect Diagram

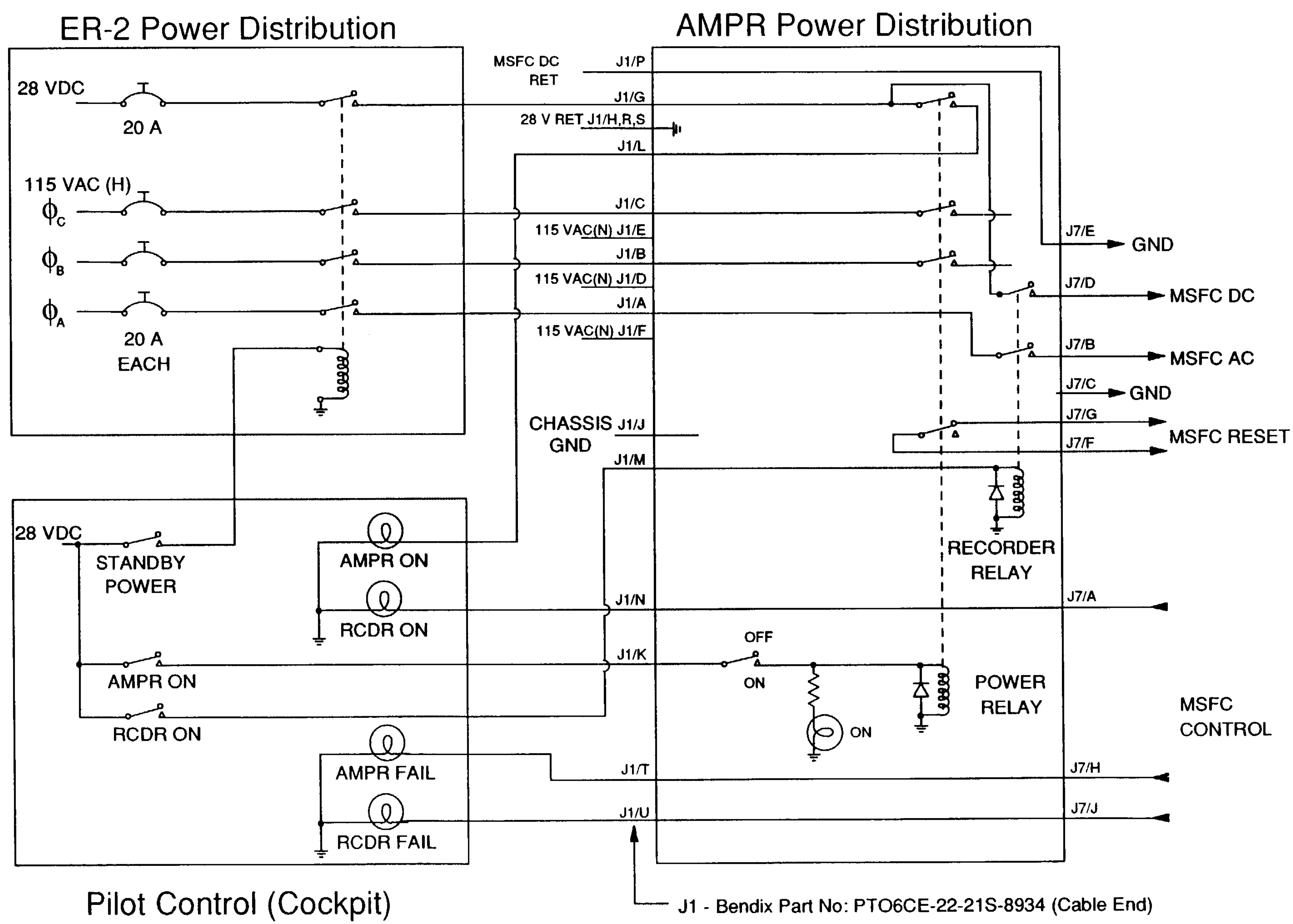


Figure 21. AMPR / ER-2 Power Interconnect Diagram

ON" light in the cockpit. In addition, the MSFC Reset lines (J7/F and J7/G) are disconnected as shown in the power schematic. The second cockpit switch, "RCDR ON," is used to energize the recorder relay internal to the AMPR power supply package. This results in aircraft power applied to the data acquisition system through pins J7/B and J7/D. A control signal (J7/A) from the data acquisition system is used to turn on the "RCDR ON" lamp inside the cockpit. Two additional control lines (J7/H and J7/J) are used to turn on the "AMPR FAIL" or "RCDR FAIL" lamps if either the radiometer or the data acquisition system have problems. The data acquisition system can be reset by turning off the "AMPR ON" power switch. This causes the MSFC Reset lines to stay common until the AMPR power is turned on again. Notice that the pilot can remove all power to the system by using the "STANDBY POWER" switch located in the cockpit.

APPENDIX A

AMPR SCANNER PROCESSOR ASSEMBLY CODE

2500 A.D. 6805 Macro Assembler - Version 4.02b

Input Filename : AMPR.ASM
Output Filename : AMPR.obj

```
                        NAM     AMPR

                *====================================================================
                *
                *                       AMPR SCANNER PROCESSOR ASSEMBLY CODE
                *
                *               THE SCANNER PROCESSOR CONTROLS THE RADIOMETER REFLECTOR
                *       STEPPER MOTOR (THROUGH A MICROSTEP SEQUENCER) TO IMPLEMENT
                *       SEVERAL SCAN MODES.  OUTPUT TIMING SIGNALS ARE PROVIDED FOR
                *       RADIOMETER DATA ACQUISITION AND REFLECTOR POSITION ACQUISITION.
                *       IN ADDITION, AN INTERACTIVE DIAGNOSTIC MODE IS PROVIDED
                *       THROUGH THE SERIAL COMMUNICATIONS INTERFACE OF THE MOTOROLA
                *       THE MC68HC705C8 SINGLE CHIP MICROCONTROLLER.
                *

                **********************************************************************
                *                       EQUATES
                *

                *               I/O REGISTERS

0000            PORTA   EQU     $0000           POSITION DATA OUT
0001            PORTB   EQU     $0001           ANALOG DATA HANDSHAKING
0002            PORTC   EQU     $0002           ENCODER POSITION IN
0003            PORTD   EQU     $0003           DTR IN;  SERIAL PORT
0004            DDRA    EQU     $0004           DIRECTION REGISTER
0005            DDRB    EQU     $0005              "         "
0006            DDRC    EQU     $0006              "         "
000A            SPCR    EQU     $000A           SPI CONTROL REGISTER
000D            BAUD    EQU     $000D           BAUD RATE REGISTER
000E            SCCR1   EQU     $000E           SCI CONTROL REGISTER 1
000F            SCCR2   EQU     $000F           SCI CONTROL REGISTER 2
0010            SCSR    EQU     $0010           SCI STATUS REGISTER
0011            SCI     EQU     $0011           SCI DATA REGISTER
0012            TCR     EQU     $0012           TIMER CONTROL REGISTER
0013            TSR     EQU     $0013           TIMER STATUS REGISTER
0014            ICRH    EQU     $0014           INPUT CAPTURE REGISTER HIGH
0015            ICRL    EQU     $0015           INPUT CAPTURE REGISTER LOW
0016            OCRH    EQU     $0016           OUTPUT COMPARE REGISTER HIGH
0017            OCRL    EQU     $0017           OUTPUT COMPARE REGISTER LOW
0018            HCOUNT  EQU     $0018           TIMER HIGH BYTE
0019            LCOUNT  EQU     $0019           TIMER LOW BYTE
001A            ALTH    EQU     $001A           COUNTER ALT REGISTER HIGH
001B            ALTL    EQU     $001B           COUNTER ALT REGISTER LOW
001C            EPROG   EQU     $001C           EPROM PROGRAM REGISTER (HC705C8)
001D            COPRR   EQU     $001D           COP (WATCHDOG) RESET REGISTER
001E            COPCR   EQU     $001E           COP CONTROL REGISTER
```

```


                  *                       REGISTER BIT DEFINITIONS

                  *                PORT A AT $0000 IS AN OUTPUT PORT, USED TO OUTPUT
                  *          AN 8 BIT REFLECTOR POSITION VALUE
                  *

                  *                PORT B           AT $0001

         0007     TEST    EQU     7             OUT;  GENERAL TEST/DIAGNOSTIC BIT
         0006     VAL     EQU     6             OUT;  DATA VALID WHEN HIGH
         0006     NVAL    EQU     6                   DATA NOT GUARANTEED WHEN LOW
         0005     SMPL    EQU     5             OUT;  HIGH TO SAMPLE
         0005     HOLD    EQU     5                   LOW TO HOLD
         0004     INT     EQU     4             OUT;  HIGH TO INTEGRATE
         0004     DUMP    EQU     4                   LOW TO DUMP
         0003     AWO     EQU     3             OUT;  ALL WINDINGS OFF WHEN LOW
         0002     CW      EQU     2             OUT;  CLOCKWISE WHEN HIGH
         0002     CCW     EQU     2                   COUNTERCLOCKWISE WHEN LOW
         0001     OE      EQU     1             OUT;  HP CHIP LOW ENABLE
         0000     HBYTE   EQU     0             OUT;  SELECT HP HIGH BYTE WHEN LOW
         0000     LBYTE   EQU     0                   SELECT HP LOW BYTE WHEN HIGH

                  *                PORT C AT $0002 IS AN INPUT PORT, USED TO READ THE
                  *          "ABSOLUTE" POSITION OF THE STEPPER MOTOR FROM THE SHAFT ENCODER
                  *          AND THE HP ENCODER INTERFACE CHIP.  THE HP CHIP INCREASES
                  *          RESOLUTION BY A FACTOR OF 4, WHICH MUST BE DEALT WITH, AS WELL
                  *          AS A CONVERSION FROM TWOS COMPLEMENT TO UNSIGNED BINARY.  THE
                  *          DATA FROM THE HP CHIP IS BASE 0, MEANING THAT WHEN THE MOTOR IS
                  *          POSITIONED AT THE ENCODER INDEX, THE DATA FROM THE HP CHIP IS 0.
                  *          VARIABLE POS IS BASE 1 (RANGE IS 1-200), AS IS THE DATA OUTPUT
                  *          TO PORT A.  THE VALUE ZERO HAS BEEN RESERVED TO INDICATE A
                  *          START OR RESTART.
                  *

                  *                PORT D           AT $0003

         0007     DTR     EQU     7             IN;   DTR ASSERTED WHEN LOW

                  *                             BIT 6 DOES NOT EXIST
                  *                             BITS 5-2 HAVE A THUMBWHEEL SWITCH ATTACHED
                  *                             BITS 1-0 ARE USED IN THE SCI

                  *                SCI SCSR     AT $0010

         0007     TDRE    EQU     7             TRANSMIT DATA REGISTER EMPTY FLAG
         0005     RDRF    EQU     5             RECEIVE DATA REGISTER FULL FLAG

                  *               TIMER CONTROL REGISTER

         0007     ICIE    EQU     7             INPUT CAPTURE INTERRUPT ENABLE
         0006     OCIE    EQU     6             OUTPUT COMPARE INTERRUPT ENABLE
         0005     TOIE    EQU     5             TIMER OVERFLOW INTERRUPT ENABLE
         0001     IEDG    EQU     1             INPUT CAPTURE EDGE; 1=POSITIVE
         0000     OLVL    EQU     0             THIS BIT PULSES STEPPER MOTOR
                          PAG
```

```
                          *              TIMER STATUS REGISTER

            0007          ICF      EQU   7                  INPUT CAPTURE FLAG
            0006          OCF      EQU   6                  OUTPUT COMPARE FLAG
            0005          TOF      EQU   5                  TIMER OVERFLOW FLAG
     0000
                          *              MEMORY MAP

            0020          ZROM     EQU   $0020              48 BYTES IN PAGE ZERO
            0050          RAM      EQU   $0050              176 BYTES IN PAGE ZERO
            0100          ROM      EQU   $0100              MAIN ROM BEGINS AT PAGE ONE
            1FDF          OPTION   EQU   $1FDF              RAM/EPROM OPTION REGISTER
            1FF4          VECTOR   EQU   $1FF4              BEGINNING OF VECTORS

                          *              OPTION REGISTER (RAM)

            0007          RAM0     EQU   7                  RAM/EPROM AT $20-$4F
            0006          RAM1     EQU   6                  RAM/EPROM AT $100-$15F
            0001          IRQL     EQU   1                  IRQ EDGE & LEVEL OR E ONLY

                          *              "FLAG" RAM VARIABLE

            0007          INDEX    EQU   7                  INDEX TRANSITION? 1=YES
            0006          HS       EQU   6                  FAST TABLE? 0=$0100; 1=$0300
            0001          ODD      EQU   1                  ODD # STEPS? 1=YES
            0000          RT       EQU   0                  DIRECTION OF RETRACE; 1=CW


                          *              MISCELLANEOUS

            000D          CR       EQU   $0D                CARRIAGE RETURN
            000A          LF       EQU   $0A                LINE FEED
            0003          ETX      EQU   $03                END OF TEXT
            0007          BEL      EQU   $07                BELL
            001B          ESC      EQU   $1B                ESCAPE
                                   PAG
```

```
0000                         .ABSOLUTE

                     **********************************************************************
                     *                            MODE 0 SUBROUTINE JUMP TABLE OFFSETS
                     *

0020                        ORG    ZROM                PAGE ZERO ROM

0020   01 00 04 07 0A OFFSET FCB    1,0,4,7,10          OFFSETS FOR MODE 0 JUMPS
0025   00 0D 10 13 00       FCB    0,13,16,19,0
002A   00 16 19 1C 00       FCB    0,22,25,28,0
002F   1F 00 22 25 00       FCB    31,0,34,37,0
0034   00 28 2B 00 00       FCB    0,40,43,0,0,0
0039   00

                     ***********************************************************************
                     *                            RAM
                     *

0050                        ORG    RAM                 112 USER BYTES AVAILABLE

0050                 POS    RMB    1                   ABSOLUTE MOTOR POSITION (1-200)
0051                 SCANS  RMB    1                   # SCANS BETWEEN CALIBRATES (n)
0052                 SCANUM RMB    1                   CURRENT SCAN NUMBER (0-{n-1})
0053                 EOS    RMB    1                   END OF SCAN; 1 PAST LAST SCAN POS
0054                 XMODE  RMB    1                   NEXT MODE AFTER MONITOR MODE
0055                 ALOOP  RMB    1                   ACQ10 LOOP COUNTER
0056                 WTEMP  RMB    1                   WAIT ROUTINE SCRATCH VARIABLE
0057                 RTEMP  RMB    1                   RLOOP ROUTINE SCRATCH VARIABLE
0058                 MSTEP  RMB    1                   STEP ROUTINE uSTEP DELAY
0059                 GSTEP  RMB    1                   FAKE SCAN POSITION COUNTER FOR GSUB
005A                 MSC    RMB    1                   MICROSTEP COUNTER
005B                 MPREV  RMB    1                   "PREVIOUS" DIST. TO DEST.
005C                 FLAG   RMB    1                   SEE EQUATES
005D                 DEST   RMB    1                   DESTINATION OF MOVE
005E                 FUDGE  RMB    1                   CORRECTION FACTOR
005F                 RLEN   RMB    1                   # BYTES OF RAMP USED
0060                 A1     RMB    1                   FOR PRESERVING A
0061                 A2     RMB    1
0062                 A3     RMB    1
0063                 A4     RMB    1
0064                 X1     RMB    1                   FOR PRESERVING X
0065                 X2     RMB    1
0066                 X3     RMB    1
0067                 X4     RMB    1
0068                 LFETCH RMB    4                   LDA ?TABLE+1,X & RTS
006C                 HFETCH RMB    4                   LDA ?TABLE  ,X & RTS
                            PAG
```

```
     0070                            .RELATIVE

     0100                            ORG     ROM

                           *****************************************************************
                           *                       MICROSTEP DELAY TABLES:  S=Kt^X
                           *
                           *               K=  25000    X=  3    TA=  5000

     0100   09C4 4A64 0C2E  FTABLE  FDB     2500,19044, 3118, 2482, 2096, 1832
     0106   09B2 0830 0728
     010C   0666 05D1 0559          FDB     1638, 1489, 1369, 1271, 1189, 1119
     0112   04F7 04A5 045F
     0118   0423 03EE 03BF          FDB     1059, 1006,  959,  917,  880,  846
     011E   0395 0370 034E
     0124   032F 0313 02F9          FDB      815,  787,  761,  737,  715,  695
     012A   02E1 02CB 02B7
     0130   02A4 0292 0281          FDB      676,  658,  641,  626,  611,  597
     0136   0272 0263 0255
     013C   0248 023C 0230          FDB      584,  572,  560,  549,  538,  528
     0142   0225 021A 0210
     0148   0206 01FD 01F4          FDB      518,  509,  500,  491,  483,  476
     014E   01EB 01E3 01DC
     0154   01D4 01CD 01C6          FDB      468,  461,  454,  447,  441,  435
     015A   01BF 01B9 01B3
     0160   01AD 01A7 01A1          FDB      429,  423,  417,  412,  407,  401
     0166   019C 0197 0191
     016C   018D 0188 0183          FDB      397,  392,  387,  383,  378,  374
     0172   017F 017A 0176
     0178   0172 016E 016A          FDB      370,  366,  362,  358,  354,  351
     017E   0166 0162 015F
     0184   015B 0158 0154          FDB      347,  344,  340,  337,  334,  331
     018A   0151 014E 014B
     0190   0148 0145 0142          FDB      328,  325,  322,  319,  316,  314
     0196   013F 013C 013A
     019C   0137 0134 0132          FDB      311,  308,  306,  303,  301,  298
     01A2   012F 012D 012A
     01A8   0128 0126 0123          FDB      296,  294,  291,  289,  287,  285
     01AE   0121 011F 011D
     01B4   011B 0119 0117          FDB      283,  281,  279,  277,  275,  273
     01BA   0115 0113 0111
     01C0   010F 010D 010B          FDB      271,  269,  267,  265,  264,  262
     01C6   0109 0108 0106
     01CC   0104 0103 0101          FDB      260,  259,  257,  255,  254,  252
     01D2   00FF 00FE 00FC
     01D8   00FB 00F9 00F8          FDB      251,  249,  248,  246,  245,  243
     01DE   00F6 00F5 00F3
     01E4   00F2 00F0 00EF          FDB      242,  240,  239,  238,  236,  235
     01EA   00EE 00EC 00EB
     01F0   00EA 00EA 00EA          FDB      234,  234,  234,  234,  234,  234
     01F6   00EA 00EA 00EA

                                    PAG
```

```
0200                             ORG     ROM+$0100

                         *               K=  5000    X=  3    TA=  1000

0200  01F4 8FB6 14D3   CTABLE   FDB      500,36790, 5331, 4244, 3584, 3133
0206  1094 0E00 0C3D
020C  0AF2 09F2 0926            FDB     2802, 2546, 2342, 2174, 2034, 1914
0212  087E 07F2 077A
0218  0712 06B8 0667            FDB     1810, 1720, 1639, 1568, 1504, 1446
021E  0620 05E0 05A6
0224  0572 0542 0515            FDB     1394, 1346, 1301, 1261, 1223, 1188
022A  04ED 04C7 04A4
0230  0484 0465 0449            FDB     1156, 1125, 1097, 1070, 1045, 1021
0236  042E 0415 03FD
023C  03E6 03D1 03BD            FDB      998,  977,  957,  938,  920,  902
0242  03AA 0398 0386
0248  0376 0366 0357            FDB      886,  870,  855,  840,  826,  813
024E  0348 033A 032D
0254  0320 0314 0308            FDB      800,  788,  776,  765,  754,  743
025A  02FD 02F2 02E7
0260  02DD 02D3 02C9            FDB      733,  723,  713,  704,  695,  686
0266  02C0 02B7 02AE
026C  02A6 029E 0296            FDB      678,  670,  662,  654,  647,  640
0272  028E 0287 0280
0278  0278 0272 026B            FDB      632,  626,  619,  612,  606,  600
027E  0264 025E 0258
0284  0252 024C 0246            FDB      594,  588,  582,  577,  571,  566
028A  0241 023B 0236
0290  0231 022B 0227            FDB      561,  555,  551,  546,  541,  536
0296  0222 021D 0218
029C  0214 020F 020B            FDB      532,  527,  523,  519,  514,  510
02A2  0207 0202 01FE
02A8  01FA 01F6 01F2            FDB      506,  502,  498,  495,  491,  487
02AE  01EF 01EB 01E7
02B4  01E4 01E0 01DD            FDB      484,  480,  477,  473,  470,  467
02BA  01D9 01D6 01D3
02C0  01CF 01CC 01C9            FDB      463,  460,  457,  454,  451,  448
02C6  01C6 01C3 01C0
02CC  01BD 01BA 01B7            FDB      445,  442,  439,  437,  434,  431
02D2  01B5 01B2 01AF
02D8  01AC 01AA 01A7            FDB      428,  426,  423,  421,  418,  416
02DE  01A5 01A2 01A0
02E4  019D 019B 0199            FDB      413,  411,  409,  406,  404,  402
02EA  0196 0194 0192
02F0  0190 0190 0190            FDB      400,  400,  400,  400,  400,  400
02F6  0190 0190 0190

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AMPR

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      0300                        ORG     ROM+$0200

                        *                 K=  20000    X=  3    TA=  5000

      0300   09C4 50E4 0D1F   STABLE FDB    2500,20708, 3359, 2674, 2258, 1974
      0306   0A72 08D2 07B6
      030C   06E5 0644 05C3          FDB    1765, 1604, 1475, 1370, 1281, 1206
      0312   055A 0501 04B6
      0318   0474 043B 0409          FDB    1140, 1083, 1033,  988,  948,  911
      031E   03DC 03B4 038F
      0324   036E 0350 0334          FDB     878,  848,  820,  794,  770,  748
      032A   031A 0302 02EC
      0330   02D8 02C5 02B3          FDB     728,  709,  691,  674,  658,  643
      0336   02A2 0292 0283
      033C   0275 0268 025B          FDB     629,  616,  603,  591,  579,  568
      0342   024F 0243 0238
      0348   022E 0224 021B          FDB     558,  548,  539,  529,  521,  512
      034E   0211 0209 0200
      0354   01F8 01F0 01E9          FDB     504,  496,  489,  482,  475,  468
      035A   01E2 01DB 01D4
      0360   01CE 01C7 01C1          FDB     462,  455,  449,  444,  438,  432
      0366   01BC 01B6 01B0
      036C   01AB 01A6 01A1          FDB     427,  422,  417,  412,  407,  403
      0372   019C 0197 0193
      0378   018E 018A 0186          FDB     398,  394,  390,  386,  382,  378
      037E   0182 017E 017A
      0384   0176 0172 016F          FDB     374,  370,  367,  363,  360,  356
      038A   016B 0168 0164
      0390   0161 015E 015B          FDB     353,  350,  347,  344,  341,  338
      0396   0158 0155 0152
      039C   014F 014C 0149          FDB     335,  332,  329,  327,  324,  321
      03A2   0147 0144 0141
      03A8   013F 013C 013A          FDB     319,  316,  314,  312,  309,  307
      03AE   0138 0135 0133
      03B4   0131 012E 012C          FDB     305,  302,  300,  298,  296,  294
      03BA   012A 0128 0126
      03C0   0124 0122 0120          FDB     292,  290,  288,  286,  284,  282
      03C6   011E 011C 011A
      03CC   0118 0117 0115          FDB     280,  279,  277,  275,  273,  272
      03D2   0113 0111 0110
      03D8   010E 010C 010B          FDB     270,  268,  267,  265,  263,  262
      03DE   0109 0107 0106
      03E4   0104 0103 0101          FDB     260,  259,  257,  256,  255,  253
      03EA   0100 00FF 00FD
      03F0   00FC 00FC 00FC          FDB     252,  252,  252,  252,  252,  252
      03F6   00FC 00FC 00FC

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0400                        ORG     ROM+$0300

                   *****************************************************************
                   *                       MONITOR MODE (MODE 0) SUBROUTINE JUMP TABLE
                   *

0400   81          JTABLE  RTS                       USED FOR UNDEFINED SUBROUTINES
0401   CC 05 5E            JMP     ASUB              ONE SCAN/CAL CYCLE
0404   CC 05 7F            JMP     CSUB              GOTO COLD LOAD
0407   CC 05 91            JMP     DSUB              TOGGLE MOTOR DIRECTION LINE
040A   CC 05 A2            JMP     ESUB              READ ENCODER CONTINUOUSLY
040D   CC 05 B5            JMP     GSUB              GET DATA FOR CURRENT POSITION
0410   CC 05 E0            JMP     HSUB              GOTO HOT LOAD
0413   CC 05 F2            JMP     ISUB              TOGGLE INTEGRATE/DUMP LINE
0416   CC 06 03            JMP     LSUB              LIST AMPR STATUS
0419   CC 06 A2            JMP     MSUB              SET EXIT MODE
041C   CC 06 BD            JMP     NSUB              SET NUMBER OF SCANS/CAL
041F   CC 06 CD            JMP     PSUB              TAKE STEP; REPORT POSITION
0422   CC 06 DB            JMP     RETURN            RETURN TO INDEX
0425   CC 06 FB            JMP     SSUB              TOGGLE SAMPLE/HOLD LINE
0428   CC 07 0C            JMP     VSUB              TOGGLE DATA VALID LINE
042B   CC 07 22            JMP     WSUB              TOGGLE WINDINGS ON/OFF

                   ***********************************************************
                   *                       MODE SELECTION JUMP TABLE
                   *

042E   CC 04 E0    MTABLE  JMP     MODE0             MONITOR MODE
0431   CC 07 B6            JMP     MODE1             SCAN MODE; 4/CAL, CCW RT
0434   CC 07 BF            JMP     MODE2             SCAN MODE; 6/CAL, CCW RT
0437   CC 07 C8            JMP     MODE3             SCAN MODE; 8/CAL, CCW RT
043A   CC 07 D1            JMP     MODE4             SCAN MODE; 10/CAL, CCW RT
043D   CC 07 DA            JMP     MODE5             SCAN MODE; 12/CAL, CCW RT
0440   CC 07 E3            JMP     MODE6             SCAN MODE; 14/CAL, CCW RT
0443   CC 07 EC            JMP     MODE7             SCAN MODE; 16/CAL, CCW RT
0446   CC 07 F5            JMP     MODE8             SCAN MODE; 4/CAL, CW RT
0449   CC 08 00            JMP     MODE9             SCAN MODE; 6/CAL, CW RT
044C   CC 08 0B            JMP     MODE10            SCAN MODE; 8/CAL, CW RT
044F   CC 08 16            JMP     MODE11            SCAN MODE; 10/CAL, CW RT
0452   CC 08 21            JMP     MODE12            TAKE DATA POINTING DOWN
0455   CC 08 52            JMP     MODE13            1KHz ON PORT A BIT 7
0458   CC 08 64            JMP     MODE14            MOTOR STEP TEST
045B   CC 08 85            JMP     MODE15            PORT "A" TEST MODE
                           PAG
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                        *************************************************************
                        *                     EXECUTION BEGINS HERE
                        *

045E  9B                RESET  SEI                 INSURE NO INTERRUPTS YET
045F  9C                       RSP                 INSURE STACK IS RESET
0460  A6 0A                    LDA    #$0A         SET MEMORY MAP AND IRQ SENSE
0462  C7 1F DF                 STA    OPTION
0465  A6 FF                    LDA    #$FF
0467  B7 04                    STA    DDRA         PORT A ALL OUTPUT
0469  B7 05                    STA    DDRB         PORT B ALL OUTPUT
046B  3F 06                    CLR    DDRC         PORT C ALL INPUT
046D  3F 5A                    CLR    MSC          MICROSTEP COUNTER
046F  1F 5C                    BCLR   INDEX,FLAG   NOT AT INDEX
0471  13 5C                    BCLR   ODD,FLAG     NOT ODD #STEPS
0473  11 5C                    BCLR   RT,FLAG      CCW RETRACE
0475  1C 5C                    BSET   HS,FLAG      USE SLOW "FAST" RAMP
0477  14 01                    BSET   CW,PORTB     CLOCKWISE
0479  16 01                    BSET   AWO,PORTB    WINDINGS ON
047B  CD 0B 0A                 JSR    PULSE        PRIME THE SEQUENCER
047E  19 01                    BCLR   DUMP,PORTB   DUMP
0480  1D 01                    BCLR   NVAL,PORTB   NO DATA VALID
0482  1B 01                    BCLR   HOLD,PORTB   HOLD
0484  1F 01                    BCLR   TEST,PORTB
0486  11 01                    BCLR   HBYTE,PORTB  HIGH BYTE OF HP CHIP
0488  12 01                    BSET   OE,PORTB     DISABLE OUTPUT OF HP CHIP
048A  3F 0A                    CLR    SPCR         DISABLE SPI
048C  A6 08                    LDA    #$08
048E  B7 0E                    STA    SCCR1        NO SCI WAKEUP
0490  A6 0C                    LDA    #$0C
0492  B7 0F                    STA    SCCR2        NO SCI INTERRUPTS
0494  A6 30                    LDA    #$30
0496  B7 0D                    STA    BAUD         9600 BAUD (4 MHz CRYSTAL)
0498  4F                       CLRA
0499  B7 00                    STA    PORTA        TELL DATA LOGGER, "RESTART"
049B  B7 50                    STA    POS          ABSOLUTE POSITION UNKNOWN
049D  4C                       INCA
049E  B7 54                    STA    XMODE        DEFAULT EXIT MODE IS 1
04A0  A6 04                    LDA    #4
04A2  B7 51                    STA    SCANS        DEFAULT TO 4 SCANS PER CALIBRATE
04A4  A6 33                    LDA    #51          END OF SCAN (1 PAST)
04A6  B7 53                    STA    EOS
04A8  A6 50                    LDA    #80
04AA  B7 58                    STA    MSTEP        SINGLE STEP TIMING
04AC  A6 D6                    LDA    #$D6         LDA QQQQ,X OPCODE
04AE  B7 68                    STA    LFETCH       PUT LDA CTABLE+,X & RTS IN RAM
04B0  B7 6C                    STA    HFETCH       PUT LDA CTABLE ,X & RTS IN RAM
04B2  4F                       CLRA                A=0
04B3  B7 6E                    STA    HFETCH+2     $02 [00]
04B5  4C                       INCA                A=1
04B6  B7 6A                    STA    LFETCH+2     $02 [01]
04B8  4C                       INCA                A=2
04B9  B7 6D                    STA    HFETCH+1     $ [02] 00
04BB  B7 69                    STA    LFETCH+1     $ [02] 01
04BD  A6 81                    LDA    #$81         RTS OPCODE
04BF  B7 6B                    STA    LFETCH+3
04C1  B7 6F                    STA    HFETCH+3     NOW CAN CHANGE TABLES
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04C3   A6 A0          LDA    #$A0         ICIE, TOIE, NEG EDGE
04C5   B7 12          STA    TCR          MAKE STEP PULSE LINE LOW
04C7   4F             CLRA
04C8   98             CLC
04C9   CD 0B 17       JSR    WAIT         WAIT FOR IT TO HAPPEN
04CC   B6 03          LDA    PORTD        READ THUMBWHEEL SWITCH
04CE   44             LSRA                MOVE BITS 5-2 TO 3-0
04CF   44             LSRA
04D0   A4 0F          AND    #$0F         MASK OFF UPPER NIBBLE
04D2   AE 03          LDX    #3
04D4   42             MUL                 COMPUTE OFFSET INTO TABLE
04D5   97             TAX
04D6   3D 1E          TST    COPCR        CLEAR POSSIBLE FLAG
04D8   A6 0F          LDA    #$0F
04DA   B7 1E          STA    COPCR        ENABLE WATCHDOG
04DC   9A             CLI                 INTERRUPTS OK NOW
04DD   DC 04 2E       JMP    MTABLE,X     JUMP INTO MODE ON SWITCH
                      PAG
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                    *=================================================================
                    *                       SCANNER MODES (0-15)
                    *=================================================================

                    *************************************************************
                    *                       MODE 0 (MONITOR MODE)
                    *
                    *              MODE 0 IS THE INTERACTIVE DIAGNOSTIC, OR "MONITOR"
                    *       MODE.  IT IS SELECTED BY SETTING THE THUMBWHEEL SWITCH TO 0
                    *       BEFORE POWER UP OF THE SYSTEM.  UPON ENTRY, THE RS-232C
                    *       DTR HARDWARE HANDSHAKE LINE IS CHECKED.  IF IT IS ACTIVE, A
                    *       COMMUNICATIONS DEVICE IS ASSUMED TO BE ATTACHED.  IF NOT,
                    *       THEN A MESSAGE IS SENT BY RS-232C INFORMING A DEVICE WHICH
                    *       MAY YET BE ATTACHED TO ACKNOWLEDGE ITS PRESENCE BY SENDING
                    *       A CARRIAGE RETURN CHARACTER.  IF THE CHARACTER IS RECEIVED,
                    *       A COMMUNICATIONS DEVICE IS ASSUMED TO BE ATTACHED.  IF THE
                    *       CHARACTER IS NOT RECEIVED, THE ENTIRE PROCESS JUST
                    *       DESCRIBED IS REPEATED.
                    *              ONCE COMMUNICATION HAS BEEN ESTABLISHED, A MENU
                    *       OF FEATURES IS SENT.  THESE FEATURES INCLUDE THE ABILITY
                    *       TO MANIPULATE THE STEPPER MOTOR AND  THE DATA ACQUISITION
                    *       HARDWARE, AND TO EXIT TO ANOTHER MODE OF OPERATION.
                    *

                    *              MONITOR MODE (MODE 0) MAIN LOOP

04E0  17 01         MODE0  BCLR    AWO,PORTB         TURN WINDINGS OFF
04E2  0F 03 1B             BRCLR   DTR,PORTD,MON     IF /DTR; ASSUME TERMINAL
04E5  5F                   CLRX                      NO /DTR; CHECK FOR TERMINAL
04E6  0F 10 FD      L0     BRCLR   TDRE,SCSR,L0      WAIT FOR TDRE
04E9  D6 0F 55             LDA     HEYYOU,X          GET CHARACTER
04EC  A1 03                CMP     #ETX              END OF MESSAGE?
04EE  27 05                BEQ     L00               IF SO, WAIT FOR INPUT
04F0  B7 11                STA     SCI               NO; SEND CHARACTER
04F2  5C                   INCX                      POINT TO NEXT CHARACTER
04F3  20 F1                BRA     L0                REPEAT UNTIL DONE
04F5  0B 10 FD      L00    BRCLR   RDRF,SCSR,L00     WAIT FOR INPUT
04F8  B6 11                LDA     SCI               GET CHARACTER
04FA  A4 7F                AND     #$7F              CLEAR UPPER BIT
04FC  A1 0D                CMP     #CR               CARRIAGE RETURN?
04FE  26 E0                BNE     MODE0             MUST ANSWER OR ASSERT /DTR
0500  5F            MON    CLRX                      RS-232 DEVICE PRESENT
0501  D6 0C 64      L1     LDA     MENU,X            GET CHARACTER
0504  0F 10 FD      L11    BRCLR   TDRE,SCSR,L11     WAIT FOR TDRE
0507  B7 11                STA     SCI               SEND CHARACTER
0509  5C                   INCX                      NEXT CHARACTER
050A  26 F5                BNE     L1                REPEAT FOR FIRST 256 BYTES
050C  D6 0D 64      L12    LDA     (MENU+256),X      NOW USING LAST PART OF MENU
050F  A1 03                CMP     #ETX              END OF MENU?
0511  27 08                BEQ     L2                IF SO, GO WAIT FOR INPUT
0513  0F 10 FD      L13    BRCLR   TDRE,SCSR,L13     WAIT FOR TDRE
0516  B7 11                STA     SCI               NO; PUT CHARACTER OUT
0518  5C                   INCX                      POINT TO NEXT CHARACTER
0519  20 F1                BRA     L12               REPEAT UNTIL DONE
051B  0B 10 FD      L2     BRCLR   RDRF,SCSR,L2      WAIT FOR INPUT
051E  B6 11                LDA     SCI               GET INPUT
0520  A4 7F                AND     #$7F              CLEAR UPPER BIT
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0522  A1 3F            CMP    #"?"          HELP REQUEST?
0524  27 DA            BEQ    MON           REPEAT MENU
0526  A4 5F            AND    #$5F          HANDLE LOWER CASE, TOO
0528  A1 58            CMP    #"X"          EXIT REQUEST?
052A  26 14            BNE    L25           CONTINUE IF NOT
052C  B6 54            LDA    XMODE         GET NEXT MODE
052E  AE 03            LDX    #3
0530  42               MUL                  COMPUTE OFFSET
0531  97               TAX
0532  4F               CLRA
0533  B7 50            STA    POS           FORCE RESYNC
0535  B7 00            STA    PORTA         REPORT RESTART
0537  1B 01            BCLR   HOLD,PORTB    RESET INITIAL CONDITIONS
0539  19 01            BCLR   DUMP,PORTB
053B  1D 01            BCLR   NVAL,PORTB
053D  DC 04 2E         JMP    MTABLE,X      ENTER NEXT MODE
0540  A0 41      L25   SUB    #"A"          ALPHA CHARACTERS ONLY
0542  2B BC            BMI    MON           REPEAT MENU IF ILLEGAL INPUT
0544  A1 19            CMP    #25           UPPER LIMIT
0546  22 B8            BHI    MON           IF LEGAL, RANGE IS NOW 0-25
0548  97               TAX
0549  EE 20            LDX    OFFSET,X      GET OFFSET INTO JUMP TABLE
054B  DD 04 00         JSR    JTABLE,X      GO TO APPROPRIATE SUBROUTINE
054E  5F               CLRX
054F  0F 10 FD   L3    BRCLR  TDRE,SCSR,L3  WAIT FOR EMPTY TRANSMITTER
0552  D6 0E 2D         LDA    PROMPT,X
0555  A1 03            CMP    #ETX          DONE?
0557  27 C2            BEQ    L2            YES; GO WAIT FOR INPUT
0559  B7 11            STA    SCI           OUTPUT PROMPT
055B  5C               INCX
055C  20 F1            BRA    L3            REPEAT UNTIL DONE
                       PAG
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                        ***********************************************************
                        *                    ASUB: DO ONE SCAN/CALIBRATE CYCLE
                        *
                        *           THIS SUBROUTINE WILL EXECUTE ONE CYCLE OF
                        *       "n" SCANS (n-1 RETRACES) PLUS A CALIBRATION
                        *

055E   CD 06 DB         ASUB    JSR     RETURN          RETURN TO INDEX POSITION
0561   4F                       CLRA                    OUTPUT POSITION = 0
0562   AE 0A                    LDX     #10             10 SETS
0564   CD 0A D8                 JSR     ACQ             10 SETS INDICATES RESTART

                        *               ENTRY POINT FOR SUBROUTINE MSLOOP

0567   10 6D            ASUB1   BSET    0,HFETCH+1      $0100 OR $0300
0569   10 69                    BSET    0,LFETCH+1
056B   0C 5C 04                 BRSET   HS,FLAG,ASUB2   SKIP IF $0300 DESIRED
056E   13 6D                    BCLR    1,HFETCH+1      $0100
0570   13 69                    BCLR    1,LFETCH+1
0572   CD 08 8E         ASUB2   JSR     SCAN            DO "N" SCANS
0575   A6 02                    LDA     #$02
0577   B7 6D                    STA     HFETCH+1        CALIBRATION SPEED
0579   B7 69                    STA     LFETCH+1
057B   CD 09 1C                 JSR     CAL             DO CALIBRATE
057E   81                       RTS

                        ****************************************************************
                        *                    CSUB: MOVE TO COLD LOAD
                        *
                        *           THE REFLECTOR WILL MOVE TO THE COLD LOAD FROM
                        *       THE CURRENT POSITION.  UPON EXIT ACCUMULATOR CONTAINS 135.
                        *

057F   3D 50            CSUB    TST     POS             IN SYNC?
0581   26 03                    BNE     CS1
0583   CD 06 DB                 JSR     RETURN          SYNC ENCODER
0586   A6 87            CS1     LDA     #135            POSITION OF COLD LOAD
0588   B1 50                    CMP     POS
058A   27 04                    BEQ     COLD            THERE ALREADY?
058C   99                       SEC                     CLOCKWISE
058D   CD 09 30                 JSR     MOVE            GO STEPPING
0590   81               COLD    RTS

                        ***********************************************************
                        *                    DSUB: DIRECTION CONTROL SUBROUTINE
                        *
                        *           THIS SUBROUTINE TOGGLES THE DIRECTION CONTROL
                        *       BIT, BIT 1 OF PORT B, AND REPORTS THE NEW STATE.
                        *

0591   05 01 07         DSUB    BRCLR   CCW,PORTB,DCW   BRANCH TO CW IF CCW
0594   15 01                    BCLR    CCW,PORTB       WAS CW; NOW CCW
0596   AE 4F                    LDX     #(CCWMSG-CV)    SAY SO
0598   CC 07 9C                 JMP     CURSUB          SNEAKY RTS
059B   14 01            DCW     BSET    CW,PORTB        WAS CCW; NOW CW
059D   AE 56                    LDX     #(CWMSG-CV)     SAY SO
059F   CC 07 9C                 JMP     CURSUB          SNEAKY RTS
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                        ************************************************************
                        *                    ESUB: ENCODER POSITION
                        *
                        *             THIS SUBROUTINE WILL OUTPUT THE ENCODER
                        *       POSITION TO THE SERIAL PORT, NONSTOP, UNTIL ANY CHARACTER
                        *       IS RECEIVED BY THE SERIAL PORT.
                        *

05A2   CD 0A B0         ESUB   JSR    GETPOS            COMPUTE POSITION
05A5   B6 50                   LDA    POS
05A7   CD 07 3B                JSR    OUT3              OUTPUT VALUE
05AA   AE 15                   LDX    #(NLMSG-CV)       CR/LF
05AC   CD 07 9C                JSR    CURSUB
05AF   0B 10 F0                BRCLR  RDRF,SCSR,ESUB    KEY PRESSED?
05B2   B6 11                   LDA    SCI               CLEAR FLAG
05B4   81                      RTS

                        ************************************************************
                        *                    GSUB: GET DATA IN CURRENT POSITION
                        *
                        *             THIS SUBROUTINE MANIPULATES THE SAMPLE/HOLD,
                        *       INTEGRATE/DUMP, AND DATA VALID LINES SO AS TO ACQUIRE
                        *       RADIOMETER DATA FOR THE CURRENT REFLECTOR POSITION.
                        *

05B5   18 01            GSUB   BSET   INT,PORTB         INTEGRATE
05B7   A6 C8                   LDA    #200
05B9   98                      CLC
05BA   CD 0B 17                JSR    WAIT              WAIT 10 MS
05BD   A6 C8                   LDA    #200
05BF   98                      CLC
05C0   CD 0B 17                JSR    WAIT              WAIT 10 MS
05C3   A6 C8                   LDA    #200
05C5   98                      CLC
05C6   CD 0B 17                JSR    WAIT              WAIT 10 MS
05C9   A6 C8                   LDA    #200
05CB   98                      CLC
05CC   CD 0B 17                JSR    WAIT              WAIT 10 MS
05CF   1D 01                   BCLR   NVAL,PORTB        DATA NOT VALID
05D1   1A 01                   BSET   SMPL,PORTB        SAMPLE
05D3   A6 C8                   LDA    #200
05D5   98                      CLC
05D6   CD 0B 17                JSR    WAIT              WAIT 10 MS
05D9   1B 01                   BCLR   HOLD,PORTB        HOLD
05DB   1C 01                   BSET   VAL,PORTB         DATA VALID
05DD   19 01                   BCLR   DUMP,PORTB        DUMP
05DF   81                      RTS
                               PAG
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                    ***********************************************************
                    *                      HSUB: MOVE TO HOT LOAD
                    *
                    *               THE REFLECTOR WILL MOVE TO THE HOT LOAD FROM THE
                    *       CURRENT POSITION.  UPON EXIT, THE ACCUMULATOR CONTAINS 117.
                    *

05E0  3D 50         HSUB    TST     POS             IN SYNC?
05E2  26 03                 BNE     HS1
05E4  CD 06 DB              JSR     RETURN          SYNC ENCODER
05E7  A6 75         HS1     LDA     #117            POSITION OF HOT LOAD
05E9  B1 50                 CMP     POS
05EB  27 04                 BEQ     HOT             THERE ALREADY?
05ED  99                    SEC                     CLOCKWISE
05EE  CD 09 30              JSR     MOVE            GO STEPPING
05F1  81            HOT     RTS

                    ***********************************************************
                    *                      ISUB: INTEGRATE/DUMP SUBROUTINE
                    *
                    *               THIS SUBROUTINE TOGGLES THE INTEGRATE/DUMP
                    *       BIT, BIT 4 OF PORT B, AND REPORTS THE NEW STATE.
                    *       A AND X ARE DESTROYED.
                    *

05F2  08 01 07      ISUB    BRSET   INT,PORTB,DMP   BRANCH TO D IF I
05F5  18 01                 BSET    INT,PORTB       WAS D; NOW I
05F7  AE 28                 LDX     #(IMSG-CV)      SAY SO
05F9  CC 07 9C              JMP     CURSUB          SNEAKY RTS
05FC  19 01         DMP     BCLR    DUMP,PORTB      WAS I; NOW D
05FE  AE 34                 LDX     #(DMSG-CV)      SAY SO
0600  CC 07 9C              JMP     CURSUB          SNEAKY RTS
                            PAG
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                    **************************************************************
                    *                   LSUB: LIST AMPR STATUS
                    *
                    *           THE CURRENT STATE OF SEVERAL IMPORTANT
                    *       SIGNALS AND VARIABLES IS REPORTED.
                    *

0603  5F            LSUB    CLRX                            HEADER
0604  CD 07 9C              JSR     CURSUB
0607  AE 3B         LW      LDX     #(WBMSG-CV)     WINDINGS
0609  CD 07 9C              JSR     CURSUB
060C  07 01 07              BRCLR   AWO,PORTB,LWF
060F  AE 46                 LDX     #(WNMSG-CV)     ON
0611  CD 07 9C              JSR     CURSUB
0614  20 05                 BRA     LD
0616  AE 4A         LWF     LDX     #(WFMSG-CV)     OFF
0618  CD 07 9C              JSR     CURSUB
061B  05 01 07      LD      BRCLR   CCW,PORTB,LDCCW
061E  AE 56                 LDX     #(CWMSG-CV)     CLOCKWISE
0620  CD 07 9C              JSR     CURSUB
0623  20 05                 BRA     LI
0625  AE 4F         LDCCW   LDX     #(CCWMSG-CV)    COUNTERCLOCKWISE
0627  CD 07 9C              JSR     CURSUB
062A  08 01 07      LI      BRSET   INT,PORTB,LINT
062D  AE 34                 LDX     #(DMSG-CV)      DUMP
062F  CD 07 9C              JSR     CURSUB
0632  20 05                 BRA     LS
0634  AE 28         LINT    LDX     #(IMSG-CV)      INTEGRATE
0636  CD 07 9C              JSR     CURSUB
0639  0A 01 07      LS      BRSET   SMPL,PORTB,LSS
063C  AE 21                 LDX     #(HMSG-CV)      HOLD
063E  CD 07 9C              JSR     CURSUB
0641  20 05                 BRA     LV
0643  AE 18         LSS     LDX     #(SMSG-CV)      SAMPLE
0645  CD 07 9C              JSR     CURSUB
0648  AE 62         LV      LDX     #(VBMSG-CV)     VALID=
064A  CD 07 9C              JSR     CURSUB
064D  0C 01 07              BRSET   VAL,PORTB,LVAL
0650  AE 6E                 LDX     #(NVMSG-CV)     LOW
0652  CD 07 9C              JSR     CURSUB
0655  20 05                 BRA     LN
0657  AE 74         LVAL    LDX     #(VMSG-CV)      HIGH
0659  CD 07 9C              JSR     CURSUB
065C  B6 51         LN      LDA     SCANS           # SCANS/CALIBRATE
065E  CD 07 3B              JSR     OUT3            DISPLAY IT
0661  AE 9F                 LDX     #(SPCMSG-CV)    FINISH TEXT
0663  CD 07 9C              JSR     CURSUB
0666  B6 54         LX      LDA     XMODE           GET EXIT MODE
0668  CD 07 3B              JSR     OUT3            DISPLAY IT
066B  AE 90                 LDX     #(XMSG-CV)      FINISH TEXT
066D  CD 07 9C              JSR     CURSUB
                            PAG
```

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                    *-------------------------------------------------------
                    *                    POSITION DISPLAY ENTRY POINT
                    *
                    *             A SUBROUTINE CALL MAY BE MADE TO "LPOS"
                    *       (WHICH IS A PART OF "LSUB") FOR THE SOLE PURPOSE
                    *       OF DISPLAYING THE CURRENT MOTOR POSITION.
                    *
                    *-------------------------------------------------------

0670  B6 50         LPOS    LDA   POS           GET MOTOR POSITION
0672  26 05                 BNE   LPOS0         ENCODER NOT IN SYNC?
0674  AE 7B                 LDX   #(NPMSG-CV)   ABSOLUTE POSITION UNKNOWN
0676  CC 07 9C              JMP   CURSUB        SNEAKY RETURN
0679  A1 01         LPOS0   CMP   #1            AT INDEX?
067B  26 07                 BNE   LPOS1
067D  AE CE                 LDX   #(NXMSG-CV)   YES
067F  CD 07 9C              JSR   CURSUB
0682  20 14                 BRA   LPOS3         GIVE POSITION
0684  A1 87         LPOS1   CMP   #135          AT COLD LOAD?
0686  26 07                 BNE   LPOS2
0688  AE C2                 LDX   #(CLMSG-CV)   YES
068A  CD 07 9C              JSR   CURSUB
068D  20 09                 BRA   LPOS3         GIVE POSITION
068F  A1 75         LPOS2   CMP   #117          AT HOT LOAD?
0691  26 05                 BNE   LPOS3
0693  AE B7                 LDX   #(HLMSG-CV)   YES
0695  CD 07 9C              JSR   CURSUB
0698  B6 50         LPOS3   LDA   POS           GET POSITION
069A  CD 07 3B              JSR   OUT3          DISPLAY IT
069D  AE 7C                 LDX   #(POSMSG-CV)  FINISH TEXT
069F  CC 07 9C              JMP   CURSUB        SNEAKY RETURN
                            PAG
```

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                        ***********************************************************
                        *                       MSUB: SELECT EXIT MODE
                        *
                        *               THIS SUBROUTINE ALLOWS FOR THE SELECTION OF
                        *       THE MODE WHICH WILL BE EXECUTED UPON EXIT FROM MODE 0
                        *       (MONITOR MODE).  THE DEFAULT IS MODE 1.
                        *

06A2   5F               MSUB    CLRX
06A3   D6 0B 70         MS1     LDA     MODES,X         DISPLAY MODES MENU
06A6   A1 03                    CMP     #ETX            END OF MENU?
06A8   27 08                    BEQ     MS3             IF SO, GO GET NEW MODE
06AA   0F 10 FD         MS2     BRCLR   TDRE,SCSR,MS2   WAIT FOR TDRE
06AD   B7 11                    STA     SCI             NO; PUT CHARACTER OUT
06AF   5C                       INCX                    POINT TO NEXT CHARACTER
06B0   20 F1                    BRA     MS1             REPEAT UNTIL DONE
06B2   AE D6            MS3     LDX     #(HXMSG-CV)
06B4   CD 07 9C                 JSR     CURSUB
06B7   CD 07 75                 JSR     HEXIN           GET ONE HEX DIGIT
06BA   B7 54                    STA     XMODE           SAVE IT
06BC   81                       RTS

                        *************************************************************
                        *                       NSUB: NUMBER OF SCANS PER CALIBRATE
                        *
                        *               THIS SUBROUTINE ALLOWS FOR THE SELECTION OF
                        *       THE NUMBER OF SCANS BETWEEN CALIBRATIONS.  THE DEFAULT
                        *       IS 4, EQUIVALENT TO MODE 1 OPERATION.  THIS COMMAND
                        *       ONLY HAS EFFECT IN MONITOR MODE (IT DOES NOT ALTER
                        *       ANY OF THE OTHER MODES).  A VALUE OF ZERO TAKEN TO BE
                        *       16 SCANS PER CALIBRATION.
                        *

06BD   AE D6            NSUB    LDX     #(HXMSG-CV)
06BF   CD 07 9C                 JSR     CURSUB
06C2   CD 07 75                 JSR     HEXIN           GET ONE HEX DIGIT
06C5   4D                       TSTA
06C6   26 02                    BNE     NSUB1           OK IF NONZERO
06C8   AB 10                    ADD     #16             MAKE IT 16 SCANS
06CA   B7 51            NSUB1   STA     SCANS           SAVE IT
06CC   81                       RTS                     THAT'S ALL FOLKS!

                        ***********************************************************
                        *                       PSUB: TAKE A STEP; REPORT POSITION
                        *

06CD   A6 C8            PSUB    LDA     #200
06CF   B7 58                    STA     MSTEP
06D1   CD 0A 46                 JSR     STEP
06D4   A6 50                    LDA     #80             RESTORE INITIAL VALUES
06D6   B7 58                    STA     MSTEP
06D8   CC 06 70                 JMP     LPOS            DISPLAY & SNEAKY RETURN
                                PAG
```

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                    ****************************************************************
                    *                     RETURN: RETURN TO INDEX POSITION
                    *
                    *         THIS SUBROUTINE WILL CAUSE THE REFLECTOR TO
                    *     RETURN BY THE SHORTEST PATH FROM THE CURRENT POSITION
                    *     TO THE START OF SCAN POSITION (DEFINED AS POSITION=1)
                    *     THE ACTUAL POSITION IS CHECKED BY READING THE SHAFT
                    *     ENCODER.
                    *

06DB  B6 50         RETURN LDA    POS              GET SUPPOSED POSITION
06DD  26 05                BNE    R1               IF ZERO, ENCODER NOT IN SYNC
06DF  CD 0A EB             JSR    SYNC             STRAIGHTEN IT OUT
06E2  20 12                BRA    R4
06E4  A1 01         R1     CMP    #1               THERE ALREADY?
06E6  27 0C                BEQ    R3
06E8  A6 64         R2     LDA    #100             COMPUTE DIRECTION
06EA  CD 0A B0             JSR    GETPOS
06ED  B1 50                CMP    POS
06EF  A6 01                LDA    #1               DESTINATION
06F1  CD 09 30             JSR    MOVE             GO STEPPING
06F4  B7 00         R3     STA    PORTA            REPORT POSITION
06F6  3F 52         R4     CLR    SCANUM
06F8  14 01                BSET   CW,PORTB         NEW DIRECTION=CW
06FA  81                   RTS                     DONE

                    ****************************************************************
                    *                     SSUB: SAMPLE/HOLD SUBROUTINE
                    *
                    *         THIS SUBROUTINE TOGGLES THE SAMPLE/HOLD BIT,
                    *     BIT 5 OF PORT B, AND REPORTS THE NEW STATE.
                    *     A AND X ARE DESTROYED.
                    *

06FB  0A 01 07      SSUB   BRSET  SMPL,PORTB,HLD   BRANCH TO H IF S
06FE  1A 01                BSET   SMPL,PORTB       WAS H; NOW S
0700  AE 18                LDX    #(SMSG-CV)       SAY SO
0702  CC 07 9C             JMP    CURSUB           SNEAKY RTS
0705  1B 01         HLD    BCLR   HOLD,PORTB       WAS S; NOW H
0707  AE 21                LDX    #(HMSG-CV)       SAY SO
0709  CC 07 9C             JMP    CURSUB           SNEAKY RTS
                           PAG
```

```
                     *************************************************************
                     *                   VSUB: DATA VALID CONTROL SUBROUTINE
                     *
                     *            THIS SUBROUTINE TOGGLES THE DATA VALID CONTROL
                     *       BIT, BIT 6 OF PORT B, AND REPORTS THE NEW STATE.
                     *       A AND X ARE DESTROYED.
                     *

070C   AE 62         VSUB    LDX     #(VBMSG-CV)
070E   CD 07 9C              JSR     CURSUB
0711   0C 01 07              BRSET   VAL,PORTB,NV    BRANCH TO LOW IF HIGH
0714   1C 01                 BSET    VAL,PORTB       WAS LOW; NOW HIGH
0716   AE 74                 LDX     #(VMSG-CV)      SAY SO
0718   CC 07 9C              JMP     CURSUB          SNEAKY RTS
071B   1D 01         NV      BCLR    NVAL,PORTB      WAS HIGH; NOW LOW
071D   AE 6E                 LDX     #(NVMSG-CV)     SAY SO
071F   CC 07 9C              JMP     CURSUB          SNEAKY RTS

                     *************************************************************
                     *                   WSUB: WINDINGS CONTROL SUBROUTINE
                     *
                     *            THIS SUBROUTINE TOGGLES THE WINDINGS CONTROL
                     *       BIT, BIT 3 OF PORT B, AND REPORTS THE NEW STATE.
                     *       A AND X ARE DESTROYED.
                     *

0722   AE 3B         WSUB    LDX     #(WBMSG-CV)
0724   CD 07 9C              JSR     CURSUB
0727   07 01 07              BRCLR   AWO,PORTB,WON   BRANCH TO ON IF OFF
072A   17 01                 BCLR    AWO,PORTB       WAS ON; NOW OFF
072C   AE 4A                 LDX     #(WFMSG-CV)     SAY SO
072E   CC 07 9C              JMP     CURSUB          SNEAKY RTS
0731   16 01         WON     BSET    AWO,PORTB       WAS OFF; NOW ON
0733   CD 0B 0A              JSR     PULSE           REPRIME THE SEQUENCER
0736   AE 46                 LDX     #(WNMSG-CV)     SAY SO
0738   CC 07 9C              JMP     CURSUB          SNEAKY RTS
                             PAG
```

```
                    *******************************************************************
                    *                     OUT3: OUTPUT 3 DIGIT DECIMAL NUMBER
                    *
                    *             THIS ROUTINE OUTPUTS TO THE SERIAL PORT
                    *       A DECIMAL VALUE (0-255) EQUIVALENT TO THE UNSIGNED
                    *       CONTENTS OF THE ACCUMULATOR.  X AND A ARE PRESERVED.
                    *

073B  B7 60         OUT3    STA    A1                SAVE A
073D  BF 64                 STX    X1                SAVE X
073F  AE 30                 LDX    #$30              ASCII ZERO
0741  A1 63         OUT31   CMP    #99               HUNDREDS DIGIT?
0743  23 05                 BLS    OUT32             SKIP IF NONE LEFT
0745  5C                    INCX
0746  A0 64                 SUB    #100              KNOCK ONE OFF
0748  20 F7                 BRA    OUT31             CHECK AGAIN
074A  A3 30         OUT32   CPX    #$30              WERE THERE ANY?
074C  27 07                 BEQ    OUT34             SKIP IF NOT
074E  0F 10 FD      OUT33   BRCLR  TDRE,SCSR,OUT33
0751  BF 11                 STX    SCI               SEND HUNDREDS DIGIT
0753  AE B0                 LDX    #$B0              BIT 7 IS FLAG
0755  A1 09         OUT34   CMP    #9                TENS DIGIT?
0757  23 05                 BLS    OUT35             SKIP IF NONE LEFT
0759  5C                    INCX
075A  A0 0A                 SUB    #10               KNOCK ONE OFF
075C  20 F7                 BRA    OUT34             CHECK AGAIN
075E  A3 30         OUT35   CPX    #$30              WERE THERE ANY?
0760  27 07                 BEQ    OUT37             SKIP IF NOT
0762  58                    ASLX                     CLEAR UPPER BIT
0763  57                    ASRX
0764  0F 10 FD      OUT36   BRCLR  TDRE,SCSR,OUT36
0767  BF 11                 STX    SCI               SEND TENS DIGIT
0769  0F 10 FD      OUT37   BRCLR  TDRE,SCSR,OUT37
076C  AB 30                 ADD    #$30              MAKE IT ASCII
076E  B7 11                 STA    SCI               SEND ONES DIGIT
0770  BE 64                 LDX    X1                RESTORE X
0772  B6 60                 LDA    A1                RESTORE A
0774  81                    RTS
                            PAG
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                         ********************************************************************
                         *                      HEXIN: GET ONE HEX DIGIT
                         *
                         *              THIS SUBROUTINE WILL WAIT FOR THE RECEIPT
                         *       BY THE SERIAL PORT (SCI) OF A HEX DIGIT (0-9,A-F),
                         *       THEN ECHO IT BACK TO THE SERIAL PORT, AND RETURN
                         *       WITH THE NUMERIC VALUE OF THE  CHARACTER IN THE
                         *       ACCUMULATOR.  IF A DISALLOWED VALUE IS RECEIVED,
                         *       IT IS IGNORED. A VALID HEX DIGIT MUST BE
                         *       RECEIVED IN ORDER TO EXIT THIS SUBROUTINE.
                         *

0775   0B 10 FD          HEXIN   BRCLR   RDRF,SCSR,HEXIN
0778   B6 11                     LDA     SCI             GET CHARACTER
077A   A4 7F                     AND     #$7F            MASK UPPER BIT
077C   97                        TAX
077D   A1 30                     CMP     #"0"
077F   25 F4                     BLO     HEXIN           OUT OF BOUNDS
0781   A1 39                     CMP     #"9"
0783   22 04                     BHI     HEX2            CHECK FOR (A-F)
0785   A0 30                     SUB     #$30            MAKE IT A NUMBER
0787   20 0D                     BRA     HECHO           ECHO IT
0789   A4 5F             HEX2    AND     #$5F            LOWER CASE OK
078B   A1 41                     CMP     #"A"
078D   25 E6                     BLO     HEXIN           OUT OF BOUNDS
078F   A1 46                     CMP     #"F"
0791   22 E2                     BHI     HEXIN           OUT OF BOUNDS
0793   97                        TAX
0794   A0 37                     SUB     #$37            MAKE IT A NUMBER
0796   0F 10 FD          HECHO   BRCLR   TDRE,SCSR,HECHO
0799   BF 11                     STX     SCI
079B   81                        RTS

                         ********************************************************************
                         *                      CURSUB: OUTPUT FROM CURRENT VALUES LIST
                         *
                         *              THIS ROUTINE WILL OUTPUT A TEXT MESSAGE FROM
                         *       THE SEQUENCE OF TEXT MESSAGES BEGINNING AT LABEL
                         *       "CV".  THE INDEX REGISTER CONTAINS UPON ENTRY
                         *       THE OFFSET INTO THIS LIST.  NOTE THAT THIS MEANS
                         *       THAT THE ENTIRE LIST CAN BE NO MORE THAN 256 BYTES.
                         *       A AND X ARE DESTROYED.
                         *
079C
079C   D6 0E 55          CURSUB  LDA     CV,X            GET CHARACTER
079F   A1 03                     CMP     #ETX            END OF MESSAGE?
07A1   27 08                     BEQ     CUR10           CURTAINS! GET IT?
07A3   0F 10 FD          CUR1    BRCLR   TDRE,SCSR,CUR1  WAIT FOR TDRE
07A6   B7 11                     STA     SCI             SEND IT
07A8   5C                        INCX                    POINT TO NEXT CHARACTER
07A9   20 F1                     BRA     CURSUB          REPEAT UNTIL DONE
07AB   81                CUR10   RTS                     YOU'RE DONE FOR
                                 PAG
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```
                  *=======================================================
                  *
                  *                      AUTONOMOUS SCAN MODES
                  *
                  *=======================================================

                  ****************************************************************
                  *                      MSLOOP: MAIN SCAN LOOP
                  *
                  *              MSLOOP IS THE MAIN LOOP FOR THE NORMAL " n
                  *       SCANS PLUS CALIBRATE, THEN REPEAT" MODE OF OPERATION.
                  *       IT IS ENTERED FROM MODES 1-10.
                  *

07AC   1B 12      MSLOOP  BCLR    TOIE,TCR        DISABLE TOF INTERRUPTS
07AE   CD 05 5E           JSR     ASUB
07B1   CD 05 67   MSL1    JSR     ASUB1           ASUB SECONDARY ENTRY POINT
07B4   20 FB              BRA     MSL1

                  *********************************************************
                  *                      MODE 1: 4 SCANS PER CALIBRATE
                  *
                  *              MODE 1 HAS CCW RETRACE.
                  *

07B6   A6 04      MODE1   LDA     #4              FOUR SCANS PER CALIBRATE
07B8   B7 51              STA     SCANS
07BA   11 5C              BCLR    RT,FLAG         CCW RETRACE
07BC   CC 07 AC           JMP     MSLOOP          BEGIN SCAN MODE

                  *********************************************************
                  *                      MODE 2: 6 SCANS PER CALIBRATE
                  *
                  *              MODE 2 HAS CCW RETRACE.
                  *

07BF   A6 06      MODE2   LDA     #6              SIX SCANS PER CALIBRATE
07C1   B7 51              STA     SCANS
07C3   11 5C              BCLR    RT,FLAG         CCW RETRACE
07C5   CC 07 AC           JMP     MSLOOP          BEGIN SCAN MODE

                  *********************************************************
                  *                      MODE 3: 8 SCANS PER CALIBRATE
                  *
                  *              MODE 3 HAS CCW RETRACE.
                  *

07C8   A6 08      MODE3   LDA     #8              EIGHT SCANS PER CALIBRATE
07CA   B7 51              STA     SCANS
07CC   11 5C              BCLR    RT,FLAG         CCW RETRACE
07CE   CC 07 AC           JMP     MSLOOP          BEGIN SCAN MODE
                          PAG
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                        ************************************************************
                        *                       MODE 4: 10 SCANS PER CALIBRATE
                        *
                        *               MODE 4 HAS CCW RETRACE.
                        *

07D1    A6 0A           MODE4   LDA     #10             TEN SCANS PER CALIBRATE
07D3    B7 51                   STA     SCANS
07D5    11 5C                   BCLR    RT,FLAG         CCW RETRACE
07D7    CC 07 AC                JMP     MSLOOP          BEGIN SCAN MODE

                        ************************************************************
                        *                       MODE 5: 12 SCANS PER CALIBRATE
                        *
                        *               MODE 5 HAS CCW RETRACE.
                        *

07DA    A6 0C           MODE5   LDA     #12             TWELVE SCANS PER CALIBRATE
07DC    B7 51                   STA     SCANS
07DE    11 5C                   BCLR    RT,FLAG         CCW RETRACE
07E0    CC 07 AC                JMP     MSLOOP          BEGIN SCAN MODE

                        ************************************************************
                        *                       MODE 6: 14 SCANS PER CALIBRATE
                        *
                        *               MODE 6 HAS CCW RETRACE.
                        *

07E3    A6 0E           MODE6   LDA     #14             FOURTEEN SCANS PER CALIBRATE
07E5    B7 51                   STA     SCANS
07E7    11 5C                   BCLR    RT,FLAG         CCW RETRACE
07E9    CC 07 AC                JMP     MSLOOP          BEGIN SCAN MODE

                        ************************************************************
                        *                       MODE 7: 16 SCANS PER CALIBRATE
                        *
                        *               MODE 7 HAS CCW RETRACE.
                        *

07EC    A6 10           MODE7   LDA     #16             SIXTEEN SCANS PER CALIBRATE
07EE    B7 51                   STA     SCANS
07F0    11 5C                   BCLR    RT,FLAG         CCW RETRACE
07F2    CC 07 AC                JMP     MSLOOP          BEGIN SCAN MODE

                                PAG
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                    ***************************************************************
                    *                       MODE 8: 4 SCANS PER CALIBRATE
                    *
                    *               MODE 8 IS IDENTICAL TO MODE 1 EXCEPT THAT THE
                    *       REFLECTOR RETRACE IS CLOCKWISE, AT HIGHER SPEED.
                    *

07F5   A6 04        MODE8   LDA     #4
07F7   B7 51                STA     SCANS           #SCANS
07F9   10 5C                BSET    RT,FLAG         CW RETRACE
07FB   1D 5C                BCLR    HS,FLAG         USE FASTER MOVE
07FD   CC 07 AC             JMP     MSLOOP

                    ***************************************************************
                    *                       MODE 9: 6 SCANS PER CALIBRATE
                    *
                    *               MODE 9 IS IDENTICAL TO MODE 2 EXCEPT THAT THE
                    *       REFLECTOR RETRACE IS CLOCKWISE, AT HIGHER SPEED.

0800   A6 06        MODE9   LDA     #6
0802   B7 51                STA     SCANS           #SCANS
0804   10 5C                BSET    RT,FLAG         CW RETRACE
0806   1D 5C                BCLR    HS,FLAG         USE FASTER MOVE
0808   CC 07 AC             JMP     MSLOOP

                    ***************************************************************
                    *                       MODE 10: 8 SCANS PER CALIBRATE
                    *
                    *               MODE 10 IS IDENTICAL TO MODE 3 EXCEPT THAT THE
                    *       REFLECTOR RETRACE IS CLOCKWISE, AT HIGHER SPEED.

080B   A6 08        MODE10  LDA     #8
080D   B7 51                STA     SCANS           #SCANS
080F   10 5C                BSET    RT,FLAG         CW RETRACE
0811   1D 5C                BCLR    HS,FLAG         USE FASTER MOVE
0813   CC 07 AC             JMP     MSLOOP

                    ***************************************************************
                    *                       MODE 11: 10 SCANS PER CALIBRATE
                    *
                    *               MODE 11 IS IDENTICAL TO MODE 4 EXCEPT THAT THE
                    *       REFLECTOR RETRACE IS CLOCKWISE, AT HIGHER SPEED.

0816   A6 0A        MODE11  LDA     #10
0818   B7 51                STA     SCANS           #SCANS
081A   10 5C                BSET    RT,FLAG         CW RETRACE
081C   1D 5C                BCLR    HS,FLAG         USE FASTER MOVE
081E   CC 07 AC             JMP     MSLOOP

                            PAG
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```
                              ************************************************************
                              *                     MODE 12
                              *
                              *              MODE 12 IMPLEMENTS A "SCAN-IN-PLACE" FUNCTION.
                              *       THE REFLECTOR WILL MOVE TO POSITION=26, SO AS TO STARE
                              *       STRAIGHT DOWN, THEN BEGIN TAKING A QUANTITY OF DATA
                              *       EQUIVALENT TO THAT OF "n" SCANS OF 50 SAMPLES EACH.
                              *       THEN A NORMAL CALIBRATION CYCLE WILL TAKE PLACE, AND
                              *       THE PROCESS REPEATS UNTIL THE ESCAPE KEY IS PRESSED.

0821  CD 06 DB                MODE12  JSR     RETURN
0824  A6 1A                   M12A    LDA     #26
0826  99                              SEC
0827  CD 09 30                        JSR     MOVE            GO STARE NADIR
082A  B7 00                           STA     PORTA           OUTPUT POSITION
082C  4F                              CLRA                    SCAN #0
082D  B7 52                   M12B    STA     SCANUM          SAVE SCAN #
082F  A6 32                           LDA     #50
0831  B7 59                           STA     GSTEP           FAKE STEP COUNTER
0833  CD 05 B5                M12C    JSR     GSUB            GET DATA FOR CURRENT POS
0836  3A 59                           DEC     GSTEP
0838  26 F9                           BNE     M12C            DONE WITH "SCAN" ?
083A  B6 52                           LDA     SCANUM
083C  4C                              INCA
083D  B1 51                           CMP     SCANS
083F  26 EC                           BNE     M12B            LAST "SCAN" ?
0841  CD 09 1C                        JSR     CAL             GO CALIBRATE
0844  0B 10 DA                        BRCLR   RDRF,SCSR,MODE12
0847  B6 11                           LDA     SCI             GET CHARACTER
0849  A4 7F                           AND     #$7F
084B  A1 1B                           CMP     #ESC            ESCAPE?
084D  26 D5                           BNE     M12A            CONTINUE IF NOT
084F  CC 04 E0                        JMP     MODE0           IF SO, MONITOR MODE

                              ************************************************************
                              *                     MODE 13
                              *
                              *              MODE 13 SIMPLY PRODUCES A 1 KHz SQUARE
                              *       WAVE ON BIT 7 OF PORT A, FOREVER.
                              *

0852  A6 0A                   MODE13  LDA     #10
0854  98                              CLC
0855  CD 0B 17                        JSR     WAIT            500uSEC LOW
0858  1E 00                           BSET    7,PORTA         TRANSITION
085A  A6 0A                           LDA     #10
085C  98                              CLC
085D  CD 0B 17                        JSR     WAIT            500uSEC HIGH
0860  1F 00                           BCLR    7,PORTA         TRANSITION
0862  20 EE                           BRA     MODE13          REPEAT
                                      PAG
```

```
                        ************************************************************
                        *                       MODE 14
                        *
                        *               MODE 14 IS A DIAGNOSTIC MODE.  THE
                        *       PURPOSE IS TO GO TO THE INDEX, THEN STEP THE
                        *       STEPPER MOTOR, USING A FAST STEP ALGORITHM,
                        *       A REVOLUTION CLOCKWISE, A REVOLUTION
                        *       COUNTERCLOCKWISE, THEN WAIT FOR A SERIAL
                        *       PORT CHARACTER BEFORE REPEATING.  IT PROMPTS
                        *       FOR A KEYPRESS UPON ENTRY SO AS TO AVOID
                        *       ACCIDENTAL INJURY TO MAN OR MACHINE.
                        *

0864    CD 06 DB        MODE14  JSR     RETURN
0867    AE F2           M14     LDX     #(KPMSG-CV)
0869    CD 07 9C                JSR     CURSUB          PROMPT FOR KEYPRESS
086C    0B 10 FD        M14A    BRCLR   RDRF,SCSR,M14A
086F    B6 11                   LDA     SCI             GET KEY
0871    CD 0A B0                JSR     GETPOS          GET CURRENT POSITION
0874    B6 50                   LDA     POS
0876    99                      SEC                     CLOCKWISE
0877    CD 09 30                JSR     MOVE
087A    CD 0A B0                JSR     GETPOS
087D    B6 50                   LDA     POS
087F    98                      CLC                     COUNTERCLOCKWISE
0880    CD 09 30                JSR     MOVE
0883    20 E2                   BRA     M14

                        ************************************************************
                        *                       MODE 15
                        *
                        *               MODE 15 IS A DIAGNOSTIC MODE.  THERE IS NO
                        *       EXIT FROM THIS MODE.  ALL IT DOES IS MAKE PORT "A"
                        *       ALL OUTPUT, THEN PROCEED TO OUTPUT CONSECUTIVE 8 BIT
                        *       VALUES TO PORT "A", WHILE OPERATING THE SAMPLE/HOLD,
                        *       INTEGRATE/DUMP, AND DATA VALID LINES.
                        *

0885    3F 00           MODE15  CLR     PORTA
0887    CD 05 B5        M15     JSR     GSUB            GET DATA
088A    3C 00                   INC     PORTA           OUTPUT NEW "FAKE" POSITION
088C    20 F9                   BRA     M15             REPEAT

                                PAG
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                         *==============================================================
                         *                          MOTION RELATED SUBROUTINES
                         *==============================================================

                         **************************************************************
                         *                          SCAN
                         *
                         *       ASSUMES INDEX POSITION (POSITION=1) AND DIRECTION=CW;
                         *       SCANS THROUGH POSITION=50; RETRACES; REPEATS FOR A
                         *       TOTAL OF "N" SCANS AND "N-1" RETRACES (ENDS UP AT
                         *       POSITION=50 OF SCAN "N").  "N" IS CONTAINED IN THE
                         *       VARIABLE "SCANS".
                         *

088E   18 01             SCAN    BSET   INT,PORTB      INTEGRATE
0890   1E 01                     BSET   TEST,PORTB     TIME SCAN CYCLE
0892   A6 00                     LDA    #0             STEP 1 IMMEDIATELY
0894   99                        SEC                   /
0895   CD 0B 17                  JSR    WAIT
0898   A6 00                     LDA    #0
089A   98                        CLC                   \
089B   CD 0B 17                  JSR    WAIT
089E   A6 A6                     LDA    #166           8.3 MS
08A0   99                        SEC                   /
08A1   CD 0B 17                  JSR    WAIT
08A4   A6 00                     LDA    #0             35 uS
08A6   98                        CLC                   \
08A7   CD 0B 17                  JSR    WAIT
08AA   A6 A6                     LDA    #166           8.3 MS
08AC   99                        SEC                   /
08AD   CD 0B 17                  JSR    WAIT
08B0   A6 00                     LDA    #0             35 uS
08B2   98                        CLC                   \
08B3   CD 0B 17                  JSR    WAIT
08B6   A6 A6                     LDA    #166           8.3 MS
08B8   99                        SEC                   /
08B9   CD 0B 17                  JSR    WAIT
08BC   A6 00                     LDA    #0             35 uS
08BE   98                        CLC                   \
08BF   CD 0B 17                  JSR    WAIT
08C2   A6 A6                     LDA    #166           8.3 MS
08C4   99                        SEC                   /
08C5   CD 0B 17                  JSR    WAIT
08C8   A6 00                     LDA    #0             35 uS
08CA   98                        CLC                   \
08CB   CD 0B 17                  JSR    WAIT
08CE   A6 85                     LDA    #133           6.65 MS
08D0   98                        CLC                   STAY LOW
08D1   CD 0B 17                  JSR    WAIT
08D4   1D 01                     BCLR   NVAL,PORTB     DATA NOT VALID
08D6   1A 01                     BSET   SMPL,PORTB     SAMPLE
08D8   A6 21                     LDA    #33            1.65 MS
08DA   99                        SEC                   /
08DB   CD 0B 17                  JSR    WAIT
08DE   A6 00                     LDA    #0             35 uS
08E0   98                        CLC
08E1   CD 0B 17                  JSR    WAIT
```

```
08E4  A6 A6                 LDA   #166         8.3 MS
08E6  98                    CLC                NO PULSE
08E7  CD 0B 17              JSR   WAIT
08EA  1B 01                 BCLR  HOLD,PORTB   HOLD
08EC  1C 01                 BSET  VAL,PORTB    DATA VALID
08EE  A6 55                 LDA   #$55         KICK THE DOG
08F0  B7 1D                 STA   COPRR
08F2  43                    COMA
08F3  B7 1D                 STA   COPRR
08F5  19 01                 BCLR  DUMP,PORTB   DUMP
08F7  CD 0A B0              JSR   GETPOS
08FA  B6 50                 LDA   POS
08FC  B1 53                 CMP   EOS          END OF SCAN?
08FE  27 04                 BEQ   SCAN2
0900  B7 00          SCAN1  STA   PORTA        OUTPUT POSITION
0902  20 8A                 BRA   SCAN         NEXT POSITION IN SCAN
0904  B6 52          SCAN2  LDA   SCANUM       GET CURRENT SCAN NUMBER
0906  4C                    INCA
0907  B1 51                 CMP   SCANS        LAST SCAN IN SET?
0909  27 10                 BEQ   SCAN3        OK; DONE
090B  B7 52                 STA   SCANUM       SAVE NEW SCAN NUMBER
090D  B6 5C                 LDA   FLAG
090F  44                    LSRA               RT,FLAG-->CARRY
0910  A6 01                 LDA   #1
0912  1F 01                 BCLR  TEST,PORTB   TIME SCAN CYCLE
0914  CD 09 30              JSR   MOVE         RETRACE
0917  14 01                 BSET  CW,PORTB     SCAN DIR=CW
0919  20 E5                 BRA   SCAN1        ESTABLISH INITIAL POSITION
091B  81             SCAN3  RTS

                     ************************************************************
                     *                 CAL: CALIBRATION CYCLE
                     *
                     *           THIS SUBROUTINE EXECUTES A CALIBRATION
                     *      CYCLE.
                     *

091C  CD 05 E0       CAL    JSR   HSUB         GO TO HOT LOAD
091F  AE 14                 LDX   #20
0921  CD 0A D8              JSR   ACQ          20 INTEGRATION TIMES
0924  CD 05 7F              JSR   CSUB         GO TO COLD LOAD
0927  AE 14                 LDX   #20
0929  CD 0A D8              JSR   ACQ          20 INTEGRATION TIMES
092C  CD 06 DB              JSR   RETURN       GOTO INDEX
092F  81                    RTS
                            PAG
```

```
                   ***************************************************************
                   *                    MOVE:  MOVE TO DESTINATION
                   *
                   *            THIS SUBROUTINE WILL CAUSE THE STEPPER MOTOR
                   *       TO MOVE TO THE DESTINATION GIVEN IN THE ACCUMULATOR.
                   *       THE DIRECTION IS GIVEN IN THE CARRY BIT, WHERE A SET
                   *       CARRY IS CLOCKWISE.  IF THE CURRENT POSITION IS THE
                   *       DESTINATION, ONE FULL REVOLUTION WILL OCCUR.
                   *       ABSOLUTE POSITION (1-200) WILL BE STORED IN "POS" AND
                   *       RETURNED IN THE ACCUMULATOR.  WHILE IN MOTION THE
                   *       VALUE $FF IS OUTPUT TO PORT A.  WHEN THE MOVE IS DONE
                   *       THE DESTINATION POSITION IS OUTPUT TO PORT A.
                   *

0930  14 01        MOVE   BSET   CW,PORTB        ASSUME CW
0932  25 02               BCS    MV0             SET CARRY=CW
0934  15 01               BCLR   CCW,PORTB       NO, IT WAS CCW
0936  AE FF        MV0    LDX    #$FF            INFORM RECORDER
0938  BF 00               STX    PORTA           MOTION TO BEGIN
093A  B7 5D               STA    DEST            SAVE DESTINATION
093C  CD 0A 77            JSR    NSTEP           CALCULATE # STEPS
093F  26 04               BNE    MV1             FULL REVOLUTION?
0941  A6 C8               LDA    #200            YES
0943  20 36               BRA    MV6             >40 STEPS
0945  A1 01        MV1    CMP    #1              JUST 1?
0947  26 03               BNE    MV2
0949  CC 0A 46            JMP    STEP            ONE STEP, THEN EXIT
094C  B7 5B        MV2    STA    MPREV           PRIME THE PUMP
094E  A1 28               CMP    #40
0950  22 29               BHI    MV6             >40 STEPS?
0952  13 5C               BCLR   ODD,FLAG        NO; <=40
0954  47                  ASRA                   HALF UP, HALF DOWN
0955  24 02               BCC    MV3             ODD #STEPS?
0957  12 5C               BSET   ODD,FLAG        YES; FLAG IT
0959  CD 09 C4     MV3    JSR    RAMPUP          RAMP UP
095C  03 5C 0A            BRCLR  ODD,FLAG,MV5
095F  1A 5A               BSET   5,MSC           COUNT TO 6
0961  99           MV4    SEC
0962  CD 0A 06            JSR    RLOOP           ODD STEP AT HIGHEST SPEED
0965  34 5A               LSR    MSC
0967  26 F8               BNE    MV4             FULL STEP?
0969  B6 5D        MV5    LDA    DEST
096B  CD 0A 77            JSR    NSTEP           HOW FAR TO GO?
096E  27 4C               BEQ    MV15            DONE?
0970  B1 5B               CMP    MPREV           GETTING CLOSER?
0972  22 3A               BHI    MV12            OVERSHOT?
0974  B7 5B               STA    MPREV           NO; SAVE NEW DIST.
0976  CD 09 E2            JSR    RAMPDN          RAMP DOWN
0979  20 2A               BRA    MV11            MAKE SURE IT'S THERE
097B  A6 14        MV6    LDA    #20             FULL RAMP LENGTH
097D  CD 09 C4            JSR    RAMPUP          RAMP UP
0980  1A 5A        MV7    BSET   5,MSC           COUNT TO 6
0982  99           MV8    SEC                    YES WE WANT A PULSE
0983  CD 0A 06            JSR    RLOOP           1 uSTEP AT FULL SPEED
0986  34 5A               LSR    MSC
0988  24 F8               BCC    MV8             FULL STEP YET?
098A  B6 5D               LDA    DEST
```

```
098C  CD 0A 77          JSR    NSTEP          HOW FAR TO GO?
098F  27 2B             BEQ    MV15           DONE?
0991  B1 5B             CMP    MPREV          GETTING CLOSER?
0993  22 19             BHI    MV12           OVERSHOT DESTINATION?
0995  B7 5B             STA    MPREV          NO; SAVE NEW DIST.
0997  A0 14             SUB    #20            RUN INTO RAMPDOWN AREA?
0999  27 05             BEQ    MV9            FULL LENGTH RAMPDOWN
099B  22 E3             BHI    MV7            NO RAMPDOWN YET
099D  40                NEGA                  OVERSHOT RAMPDOWN
099E  20 02             BRA    MV10           RECALCULATE RAMPDOWN LENGTH
09A0  A6 14       MV9   LDA    #20            FULL RAMP DOWN
09A2  CD 09 E2    MV10  JSR    RAMPDN         RAMP DOWN
09A5  B6 5D       MV11  LDA    DEST
09A7  CD 0A 77          JSR    NSTEP          HOW FAR TO GO?
09AA  27 10             BEQ    MV15           DONE?
09AC  2A 09             BPL    MV14           JUST SHY OF TARGET
09AE  04 01 04    MV12  BRSET  CW,PORTB,MV13  OVERSHOT; REVERSE DIRECTION
09B1  14 01             BSET   CW,PORTB
09B3  20 02             BRA    MV14
09B5  15 01       MV13  BCLR   CCW,PORTB
09B7  CD 0A 46    MV14  JSR    STEP
09BA  20 E9             BRA    MV11           CHECK AGAIN
09BC  CD 0A B0    MV15  JSR    GETPOS
09BF  B6 50             LDA    POS            EXIT W/POS IN A
09C1  B7 00             STA    PORTA          SEND TO RECORDER
09C3  81                RTS
                        PAG
```

```
                        *****************************************************************
                        *                      RAMPUP
                        *
                        *            THIS SUBROUTINE USES A TABLE OF MOTOR ACCELERATION
                        *     CURVE MICROSTEP DELAY VALUES TO ACCELERATE THE MOTOR TO HIGH
                        *     SPEED.  UPON ENTRY, THE ACCUMULATOR CONTAINS THE NUMBER OF
                        *     FULL STEPS TO RAMP UP (1-20).

09C4   AE 0C            RAMPUP  LDX     #12             2 BYTES x 6 uSTEPS
09C6   42                       MUL                     X=0 AFTER
09C7   B7 5F                    STA     RLEN            #BYTES OF RAMP
09C9   1A 5A                    BSET    5,MSC           COUNT TO 6
09CB   99               RU0     SEC                     YES WE WANT A PULSE
09CC   AD 38                    BSR     RLOOP           ONE MICROSTEP
09CE   34 5A                    LSR     MSC
09D0   24 09                    BCC     RU2             FULL STEP YET?
09D2   B6 5D            RU1     LDA     DEST
09D4   CD 0A 77                 JSR     NSTEP           HOW FAR TO GO?
09D7   B7 5B                    STA     MPREV           SAVE DISTANCE
09D9   1A 5A                    BSET    5,MSC           RESET COUNTER
09DB   5C               RU2     INCX                    POINT TO NEXT DATA
09DC   5C                       INCX
09DD   B3 5F                    CPX     RLEN            DONE RAMPING?
09DF   26 EA                    BNE     RU0             REPEAT IF NOT
09E1   81               RU3     RTS

                        *****************************************************************
                        *                      RAMPDN
                        *
                        *            THIS SUBROUTINE USES A TABLE OF MOTOR DECELERATION
                        *     CURVE MICROSTEP DELAY VALUES TO DECELERATE THE MOTOR TO
                        *     LOW SPEED OR STOP.  UPON ENTRY, THE ACCUMULATOR CONTAINS
                        *     THE NUMBER OF FULL STEPS TO RAMP DOWN (1-20).

09E2   AE 0C            RAMPDN  LDX     #12             2 BYTES x 6 uSTEPS
09E4   42                       MUL                     X=0 AFTER
09E5   97                       TAX                     NOW START AT TOP
09E6   1A 5A                    BSET    5,MSC           COUNT TO 6
09E8   99               RD0     SEC                     YES WE WANT A PULSE
09E9   AD 1B                    BSR     RLOOP           ONE MICROSTEP
09EB   34 5A                    LSR     MSC
09ED   24 0F                    BCC     RD2             FULL STEP YET?
09EF   B6 5D            RD1     LDA     DEST
09F1   CD 0A 77                 JSR     NSTEP           HOW FAR TO GO?
09F4   27 0F                    BEQ     RD3             AT DESTINATION?  THEN QUIT
09F6   B1 5B                    CMP     MPREV           GETTING CLOSER?
09F8   22 0B                    BHI     RD3             OVERSHOT?  THEN QUIT
09FA   B7 5B                    STA     MPREV           SAVE DISTANCE
09FC   1A 5A                    BSET    5,MSC           RESET COUNTER
09FE   5A               RD2     DECX                    POINT TO NEXT DATA
09FF   5A                       DECX
0A00   26 E6                    BNE     RD0             BOTTOM OF RAMP?
0A02   98                       CLC                     NO PULSE
0A03   AD 01                    BSR     RLOOP           SETTLING TIME
0A05   81               RD3     RTS                     LET'S "GIT"
                                PAG
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                        ********************************************************************
                        *                      RLOOP
                        *
                        *             THIS SUBROUTINE CAUSES A DELAY, FOLLOWED BY
                        *       AN OLVL TRANSFER.  THE TWO BYTE DELAY VALUE IS POINTED TO
                        *       BY THE INDEX REGISTER, MS BYTE FIRST.  A PULSE WILL OCCUR
                        *       IF THE CARRY BIT IS FOUND TO BE SET UPON ENTRY.

0A06    B6 1A           RLOOP   LDA     ALTH            INHIBIT ALTL
0A08    B7 16                   STA     OCRH            INHIBIT COMPARE
0A0A    24 02                   BCC     RLO             C=1 FOR PULSE
0A0C    10 12                   BSET    OLVL,TCR
0A0E    BD 68           RLO     JSR     LFETCH          DOES   LDA ?TABLE+1,X
0A10    BB 1B                   ADD     ALTL            SUM LSB
0A12    B7 57                   STA     RTEMP
0A14    BD 6C                   JSR     HFETCH          DOES   LDA ?TABLE,X
0A16    B9 16                   ADC     OCRH            SUM MSB
0A18    B7 16                   STA     OCRH            OUTPUT COMPARE
0A1A    B6 13                   LDA     TSR             CLEAR FLAGS
0A1C    B6 57                   LDA     RTEMP
0A1E    B7 17                   STA     OCRL            OUTPUT COMPARE ENABLED
0A20    A6 55                   LDA     #$55            KICK THE DOG
0A22    B7 1D                   STA     COPRR
0A24    43                      COMA
0A25    B7 1D                   STA     COPRR
0A27    0D 13 FD        RL1     BRCLR   OCF,TSR,RL1     WAIT FOR OLVL TRANSFER
0A2A    B6 1A                   LDA     ALTH            INHIBIT ALTL
0A2C    B7 16                   STA     OCRH            INHIBIT COMPARE
0A2E    11 12                   BCLR    OLVL,TCR        FALLING EDGE
0A30    B6 1B                   LDA     ALTL
0A32    AB 0D                   ADD     #13             SUM LSB
0A34    B7 57                   STA     RTEMP
0A36    B6 16                   LDA     OCRH
0A38    A9 00                   ADC     #0              SUM MSB
0A3A    B7 16                   STA     OCRH            OUTPUT COMPARE
0A3C    B6 13                   LDA     TSR             CLEAR FLAGS
0A3E    B6 57                   LDA     RTEMP
0A40    B7 17                   STA     OCRL            OUTPUT COMPARE ENABLED
0A42    0D 13 FD        RL2     BRCLR   OCF,TSR,RL2     WAIT FOR OLVL TRANSFER
0A45    81                      RTS
                                PAG
```

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                          **************************************************************
                          *                       STEP: STEP ONE STEP
                          *
                          *            THIS SUBROUTINE WILL CAUSE SIX POSITIVE
                          *      (__-__) PULSES ON THE STEP PULSE LINE OF THE STEPPER
                          *      MOTOR TRANSLATOR, WHICH IS ATTACHED TO THE OUTPUT
                          *      COMPARE LINE OF THE MICROCONTROLLER.  THE WATCHDOG
                          *      TIMER WILL BE REFRESHED.  THE STEP PULSE WIDTH IS 35
                          *      MICROSECONDS.  IF THIS ROUTINE IS CALLED BEFORE
                          *      THE ENCODER IS IN SYNC, THE VARIABLE POS WILL
                          *      REMAIN ZERO, SO AS TO INDICATE UNRELIABLE POSITION
                          *      DATA FROM THE ENCODER.
                          *

0A46   BF 67              STEP   STX      X4
0A48   06 01 05                  BRSET    AWO,PORTB,STO    WINDINGS ON?
0A4B   16 01                     BSET     AWO,PORTB        WINDINGS MUST BE ON
0A4D   CD 0B 0A                  JSR      PULSE            __-__ (PRIME IT)
0A50   CD 0B 0A           STO    JSR      PULSE            PULSE #1
0A53   18 5A                     BSET     4,MSC            5 MORE
0A55   B6 58              ST1    LDA      MSTEP            GET uSTEP DELAY
0A57   99                        SEC                       RISING EDGE
0A58   CD 0B 17                  JSR      WAIT
0A5B   4F                        CLRA
0A5C   98                        CLC                       FALLING EDGE
0A5D   CD 0B 17                  JSR      WAIT
0A60   34 5A                     LSR      MSC
0A62   24 F1                     BCC      ST1              FULL STEP YET?
0A64   A6 55                     LDA      #$55             KICK THE DOG
0A66   B7 1D                     STA      COPRR
0A68   43                        COMA
0A69   B7 1D                     STA      COPRR
0A6B   B6 50                     LDA      POS              IN SYNC?
0A6D   27 05                     BEQ      ST2              CONTINUE TO REPORT 0
0A6F   CD 0A B0                  JSR      GETPOS           RETURN W/POS IN A
0A72   B6 50                     LDA      POS
0A74   BE 67              ST2    LDX      X4
0A76   81                        RTS
                                 PAG
```

```
                        ******************************************************************
                        *                         NSTEP:  COMPUTE STEPS TO DESTINATION
                        *
                        *               THIS SUBROUTINE COMPUTES THE NUMBER OF STEPS
                        *       BETWEEN THE CURRENT POSITION AND A DESTINATION GIVEN IN THE
                        *       ACCUMULATOR.  THE DIRECTION OF MOVEMENT IS ASSUMED TO BE
                        *       THE CURRENT MOTOR DIRECTION.  THE RESULT IS RETURNED IN
                        *       THE ACCUMULATOR.  INPUT IS ASSUMED TO BE IN THE 1-200 RANGE.
                        *

0A77    BF 66           NSTEP   STX     X3
0A79    3F 5E                   CLR     FUDGE           CORRECT FOR INDEX
0A7B    CD 0A B0                JSR     GETPOS
0A7E    B0 50                   SUB     POS             CHECK ENCODER DATA
0A80    27 18                   BEQ     NS5             ALREADY HERE! QUIT
0A82    25 07                   BLO     NS2
0A84    04 01 0B                BRSET   CW,PORTB,NS4    CW?
0A87    AE 38                   LDX     #56             NEW CORRECTION
0A89    20 05                   BRA     NS3
0A8B    05 01 04        NS2     BRCLR   CCW,PORTB,NS4   CCW?
0A8E    AE C8                   LDX     #200            NEW CORRECTION
0A90    BF 5E           NS3     STX     FUDGE
0A92    BE 66           NS4     LDX     X3
0A94    BB 5E                   ADD     FUDGE           ADD CORRECTION
0A96    04 01 01                BRSET   CW,PORTB,NS5    CW?
0A99    40                      NEGA
0A9A    81              NS5     RTS                     CONDITION CODES FOR "A"

                        ******************************************************************
                        *                         NPOS: COMPUTE NEXT POSITION
                        *
                        *               THIS ROUTINE COMPUTES A NEW POSITION, ONE STEP FROM
                        *       THE CURRENT POSITION, BASED ON THE CURRENT MOTOR DIRECTION.
                        *       THE RESULT IS RETURNED IN THE ACCUMULATOR.
                        *

0A9B    A6 01           NPOS    LDA     #1              ONE STEP
0A9D    04 01 01                BRSET   CW,PORTB,NP1    NEG OR POS?
0AA0    40                      NEGA
0AA1    BB 50           NP1     ADD     POS             COMPUTE
0AA3    26 04                   BNE     NP2             ZERO?
0AA5    A6 C8                   LDA     #200            YES;CORRECT TO 200
0AA7    20 06                   BRA     NP3
0AA9    A1 C9           NP2     CMP     #201            NOT ZERO; 201?
0AAB    26 02                   BNE     NP3             NEITHER, SO LEGAL
0AAD    A6 01                   LDA     #1              CORRECT 201 TO 1
0AAF    81              NP3     RTS
                                PAG
```

```
                    *******************************************************************
                    *                       GETPOS: READ POSITION FROM ENCODER
                    *
                    *               THIS SUBROUTINE READS THE HP HCTL-2000 ENCODER
                    *       INTERFACE CHIP, DOES A DIVIDE-BY-FOUR ON THE 10 BIT 4x
                    *       RESOLUTION DATA, AND CONVERTS IT TO AN 8 BIT UNSIGNED
                    *       ABSOLUTE POSITION VALUE IN THE RANGE 1-200, WHERE VALUES
                    *       INCREASE WITH CLOCKWISE MOTION,AND A VALUE OF 1 REPRESENTS
                    *       THE ENCODER INDEX.  THE RESULT IS PLACED IN "POS".
                    *

0AB0  B7 61         GETPOS  STA    A2               SAVE A
0AB2  BF 65                 STX    X2               SAVE X
0AB4  1F 5C         GP0     BCLR   INDEX,FLAG
0AB6  13 01                 BCLR   OE,PORTB         OUTPUT ENABLE
0AB8  BE 02                 LDX    PORTC            HIGH BYTE
0ABA  10 01                 BSET   LBYTE,PORTB
0ABC  B6 02                 LDA    PORTC            LOW BYTE
0ABE  12 01                 BSET   OE,PORTB         OUTPUT DISABLE
0AC0  11 01                 BCLR   HBYTE,PORTB      RESET SEL
0AC2  0E 5C EF              BRSET  INDEX,FLAG,GP0   IF CORRUPTED, REPEAT
0AC5  56                    RORX                    SHIFT 2 BITS RIGHT
0AC6  46                    RORA
0AC7  56                    RORX
0AC8  46                    RORA
0AC9  27 05                 BEQ    GP1
0ACB  56                    RORX                    WHICH DIR FROM INDEX?
0ACC  24 02                 BCC    GP1
0ACE  A0 38                 SUB    #56              SUBTRACT IF CCW
0AD0  4C            GP1     INCA                    MAKE IT 1-200
0AD1  B7 50                 STA    POS
0AD3  BE 65                 LDX    X2
0AD5  B6 61                 LDA    A2
0AD7  81                    RTS

                    *******************************************************************
                    *                       ACQ: ACQUIRE DATA SETS WHILE STATIONARY
                    *
                    *               THIS SUBROUTINE WILL ACQUIRE RADIOMETER DATA "n"
                    *       TIMES IN THE CURRENT POSITION, AND WILL OUTPUT (TO PORT A) AS
                    *       POSITION DATA THE VALUE FOUND IN THE ACCUMULATOR UPON ENTRY.
                    *       THIS IS SO THE ROUTINE MAY BE USED TO GENERATE THE 10 ZERO
                    *       POSITIONS REQUIRED TO INDICATE STARTUP OR RESTART, AS WELL AS
                    *       THE CALIBRATION INTEGRATIONS.  "n" IS FOUND IN THE X REGISTER.
                    *

0AD8  B7 00         ACQ     STA    PORTA            POSITION REPORT
0ADA  BF 55                 STX    ALOOP            SAVE COUNT
0ADC  CD 05 B5      ACQL    JSR    GSUB             GET DATA
0ADF  A6 55                 LDA    #$55             KICK THE DOG
0AE1  B7 1D                 STA    COPRR
0AE3  43                    COMA
0AE4  B7 1D                 STA    COPRR
0AE6  3A 55                 DEC    ALOOP            ONE DOWN
0AE8  26 F2                 BNE    ACQL             ANY TO GO?
0AEA  81                    RTS                     ALL DONE
                            PAG
```

```
                        *******************************************************************
                        *                         SYNC: SYNCHRONIZE ENCODER LOGIC
                        *
                        *               THIS SUBROUTINE CAUSES THE REFLECTOR TO MOVE UNTIL
                        *       THE ENCODER INDEX IS REACHED, A MAXIMUM OF ONE REVOLUTION,
                        *       SO THAT THE INCREMENTAL TO ABSOLUTE ENCODE LOGIC WILL SYNC
                        *       TO THE INDEX POSITION OF THE INCREMENTAL SHAFT ENCODER.
                        *

0AEB  1F 12             SYNC    BCLR    ICIE,TCR        DISABLE INPUT CAPTURE IRQ
0AED  3D 13                     TST     TSR             CLEAR ANY PENDING IRQ
0AEF  3D 15                     TST     ICRL            CLEAR ICF
0AF1  13 12                     BCLR    IEDG,TCR        FALLING EDGE DETECT
0AF3  14 01                     BSET    CW,PORTB        GO CLOCKWISE
0AF5  CD 0A 46          SYNC1   JSR     STEP            TAKE A STEP
0AF8  0F 13 FA                  BRCLR   ICF,TSR,SYNC1   INDEX ENCOUNTERED?
0AFB  3D 15                     TST     ICRL            CLEAR ICF
0AFD  1E 5C                     BSET    INDEX,FLAG      INDEX TRANSITION
0AFF  A6 01                     LDA     #1
0B01  B7 50                     STA     POS             ESTABLISH INITIAL POSITION
0B03  B7 00                     STA     PORTA
0B05  12 12                     BSET    IEDG,TCR        DETECT STEP FROM INDEX
0B07  1E 12                     BSET    ICIE,TCR        ENABLE INPUT CAPTURE IRQ
0B09  81                        RTS                     RETURN W/POS (=1) IN A

                        **************************************************************
                        *                         PULSE: SINGLE MICROSTEP PULSE
                        *
                        *               THIS SUBROUTINE SIMPLY CAUSES ONE LOW-HIGH-LOW
                        *       (__-__) PULSE ON THE MOTOR MICROSTEP SEQUENCER STEP
                        *       LINE.  THE ROUTINE IS USED BY THE PSUB ROUTINE IN
                        *       MICROSTEPPING, AND TO "PRIME" THE SEQUENCER AFTER ANY
                        *       TIME THE "ALL WINDINGS OFF" LINE MAKES A POSITIVE
                        *       TRANSITION.  THE STEP LINE IS ASSUMED TO BE LOW UPON
                        *       ENTRY.
                        *

0B0A  A6 00             PULSE   LDA     #0
0B0C  99                        SEC
0B0D  CD 0B 17                  JSR     WAIT            MINIMUM DELAY BEFORE LOW
0B10  A6 00                     LDA     #0              MIN TIME IS 35 uS
0B12  98                        CLC
0B13  CD 0B 17                  JSR     WAIT            WAIT
0B16  81                        RTS
                                PAG
```

```
                         ***************************************************************
                         *                      WAIT: WAIT ROUTINE
                         *
                         *              THIS SUBROUTINE CAUSES A DELAY OF AN INTEGER
                         *      MULTIPLE OF 50 MICROSECONDS OF THE VALUE FOUND IN THE
                         *      ACCUMULATOR UPON ENTRY.  THIS ROUTINE USES THE TIMER
                         *      FUNCTION, AND THE OLVL VALUE IS TRANSFERED AT THE END
                         *      OF THE DELAY, AS THE OUTPUT COMPARE FLAG IS SET.  IF
                         *      THE REQUESTED DELAY IS ZERO, THERE IS A 35 uSEC DELAY.
                         *      THIS DELAY IS DUE TO THE OVERHEAD REQUIRED TO SET UP
                         *      AN "IMMEDIATE" OUTPUT COMPARE AND OLVL TRANSFER.  THE
                         *      DESIRED OLVL LEVEL IS PASSED THROUGH THE CARRY BIT
                         *      UPON ENTRY; C=1 FOR HIGH, OR C=0 FOR LOW.  THE DELAY
                         *      INCLUDES TIME FOR THE INVOCATION OF THIS ROUTINE AS
                         *      FOLLOWS:
                         *                      LDA     #___
                         *                      SEC             (OR CLC)
                         *                      JSR     WAIT
                         *
                         *              THE DELAY IS MEASURED TO THE OLVL TRANSFER.
                         *      AN ADDITIONAL 4 uS ELAPSES BEFORE PROGRAM CONTROL
                         *      IS RETURNED.
                         *

0B17  9B                 WAIT    SEI                     MASK INTERRUPTS
0B18  BE 1A                      LDX     ALTH            (3) COUNTER HIGH
0B1A  BF 16                      STX     OCRH            (4)
0B1C  10 12                      BSET    OLVL,TCR
0B1E  25 02                      BCS     WAIT0           WHAT'S OLVL GOING TO BE?
0B20  11 12                      BCLR    OLVL,TCR
0B22  4D                 WAIT0   TSTA                    (3) ZERO WAIT?
0B23  26 05                      BNE     WAIT1           (3)
0B25  5F                         CLRX                    (3)
0B26  A6 0F                      LDA     #15             (2) 35 uSEC
0B28  20 09                      BRA     WAIT2           (3)
0B2A  AE 19              WAIT1   LDX     #25             (2) 25 COUNTS = 50 uSEC
0B2C  42                         MUL                     (11)
0B2D  A0 04                      SUB     #4              (2) COMPENSATE FOR ENTRY/EXIT
0B2F  24 02                      BCC     WAIT2           (3) BORROW?
0B31  5A                         DECX                    (3) YES; DECREMENT UPPER BYTE
0B32  98                         CLC                     (2)
0B33  BB 1B              WAIT2   ADD     ALTL            (3) COMPUTE NEW COUNT
0B35  B7 56                      STA     WTEMP           (4)
0B37  9F                         TXA                     (2)
0B38  B9 16                      ADC     OCRH            (3) COMPUTE NEW COUNT
0B3A  B7 16                      STA     OCRH            (4) COMPARE INHIBITED
0B3C  B6 13                      LDA     TSR             (3) CLEAR OCF
0B3E  B6 56                      LDA     WTEMP           (3)
0B40  B7 17                      STA     OCRL            (4) ENABLE COMPARE
0B42  0D 13 FD           WAIT3   BRCLR   OCF,TSR,WAIT3   (5) WAIT FOR OCF
0B45  9A                         CLI
0B46  81                         RTS                     (6)
                                 PAG
```

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                      *****************************************************************
                      *                      INTERRUPT SERVICE ROUTINES
                      *

0B47   80             SPIRQ   RTI                        NOT USED
0B48   80             SCIRQ   RTI                        NOT USED
0B49   80             SWI     RTI                        NOT USED

                      *----------------------------------------------------------------
                      *                      IRQ: IRQ LINE SERVICE ROUTINE
                      *
                      *            THIS ROUTINE ALLOWS FOR THE TESTING OF THE
                      *       WATCHDOG TIMER, AS WELL AS AN EXTERNAL HARDWARE FAILURE
                      *       FUNCTION.  AS ENVISIONED, ATTACHED UNITS (POWER SUPPLIES,
                      *       ETC.) WOULD CAUSE A FALLING EDGE UPON FAILURE, CAUSING A
                      *       WATCHDOG TIMEOUT, FOLLOWED BY A RESTART, THEREBY CREATING
                      *       A RECORD IN THE DATA OF THE OCCURRENCE OF A FAILURE.
                      *       THE VERSION NUMBER OF THIS AMPR SOFTWARE IS SENT VIA
                      *       RS-232, FOLLOWED BY A WAIT, WHICH WILL RESULT IN THE
                      *       TIMEOUT, WHICH IN TURN WILL CAUSE A SYSTEM RESET.
                      *

0B4A   AE 0C          IRQ     LDX     #(VER-CV)          VERSION #
0B4C   CD 07 9C               JSR     CURSUB
0B4F   20 FE          IRQ1    BRA     IRQ1               WAIT FOR DEATH

                      *****************************************************************
                      *                      TIRQ: TIMER INTERRUPT SERVICE ROUTINE
                      *
                      *
                      *            THIS ROUTINE CHECKS FIRST FOR TIMER OVERFLOW,
                      *       USED AS A REMINDER TO REFRESH THE WATCHDOG TIMER.  THEN
                      *       A CHECK IS MADE FOR INPUT CAPTURE, SO AS TO DETERMINE
                      *       WHETHER THE MOTOR HAS JUST TRANSITED THE INDEX.
                      *

0B51   0B 12 0C       TIRQ    BRCLR   TOIE,TCR,TI0       SKIP IF NOT ENABLED
0B54   0B 13 09               BRCLR   TOF,TSR,TI0        SKIP IF NO OVERFLOW
0B57   B6 19                  LDA     LCOUNT             CLEAR TOF
0B59   A6 55                  LDA     #$55               KICK THE DOG
0B5B   B7 1D                  STA     COPRR
0B5D   43                     COMA
0B5E   B7 1D                  STA     COPRR
0B60   0F 13 0C       TI0     BRCLR   ICF,TSR,TI2        SKIP IF NO TRANSITION
0B63   B6 15                  LDA     ICRL               CLEAR FLAG
0B65   1E 5C                  BSET    INDEX,FLAG         FLAG INDEX TRANSITION
0B67   02 12 03               BRSET   IEDG,TCR,TI1       SKIP IF LEAVING INDEX
0B6A   12 12                  BSET    IEDG,TCR           NEXT LOOK FOR STEP AWAY
0B6C   80                     RTI                        DONE!
0B6D   13 12          TI1     BCLR    IEDG,TCR           NEXT LOOK FOR INDEX
0B6F   80             TI2     RTI                        GET OUT!
                              PAG
```

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                         *****************************************************************
                         *                       MODES MENU  (MAXIMUM 255 CHARACTERS!!!)

0B70   0D 0A 0D 0A       MODES   FCB     CR,LF,CR,LF
0B74   4D 4F 44 45               FCC     "MODE"
0B78   0D 0A 0D 0A               FCB     CR,LF,CR,LF
0B7C   30 20 3D 20 4D            FCC     "0 = MONITOR MODE"
0B81   4F 4E 49 54 4F
0B86   52 20 4D 4F 44
0B8B   45
0B8C   0D 0A                     FCB     CR,LF
0B8E   31 20 3D 20 34            FCC     "1 = 4/CCW"
0B93   2F 43 43 57
0B97   0D 0A                     FCB     CR,LF
0B99   32 20 3D 20 36            FCC     "2 = 6/CCW"
0B9E   2F 43 43 57
0BA2   0D 0A                     FCB     CR,LF
0BA4   33 20 3D 20 38            FCC     "3 = 8/CCW"
0BA9   2F 43 43 57
0BAD   0D 0A                     FCB     CR,LF
0BAF   34 20 3D 20 31            FCC     "4 = 10/CCW"
0BB4   30 2F 43 43 57
0BB9   0D 0A                     FCB     CR,LF
0BBB   35 20 3D 20 31            FCC     "5 = 12/CCW"
0BC0   32 2F 43 43 57
0BC5   0D 0A                     FCB     CR,LF
0BC7   36 20 3D 20 31            FCC     "6 = 14/CCW"
0BCC   34 2F 43 43 57
0BD1   0D 0A                     FCB     CR,LF
0BD3   37 20 3D 20 31            FCC     "7 = 16/CCW"
0BD8   36 2F 43 43 57
0BDD   0D 0A                     FCB     CR,LF
                                 PAG
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0BDF   38 20 3D 20 34        FCC    "8 = 4/CW"
0BE4   2F 43 57
0BE7   0D 0A                 FCB    CR,LF
0BE9   39 20 3D 20 36        FCC    "9 = 6/CW"
0BEE   2F 43 57
0BF1   0D 0A                 FCB    CR,LF
0BF3   41 20 3D 20 38        FCC    "A = 8/CW"
0BF8   2F 43 57
0BFB   0D 0A                 FCB    CR,LF
0BFD   42 20 3D 20 31        FCC    "B = 10/CW"
0C02   30 2F 43 57
0C06   0D 0A                 FCB    CR,LF
0C08   43 20 3D 20 41        FCC    "C = ACQUIRE STARING NADIR"
0C0D   43 51 55 49 52
0C12   45 20 53 54 41
0C17   52 49 4E 47 20
0C1C   4E 41 44 49 52
0C21   0D 0A                 FCB    CR,LF
0C23   44 20 3D 20 31        FCC    "D = 1KHz ON PORT A BIT 7"
0C28   4B 48 7A 20 4F
0C2D   4E 20 50 4F 52
0C32   54 20 41 20 42
0C37   49 54 20 37
0C3B   0D 0A                 FCB    CR,LF
0C3D   45 20 3D 20 4D        FCC    "E = MOTOR STEP TEST"
0C42   4F 54 4F 52 20
0C47   53 54 45 50 20
0C4C   54 45 53 54
0C50   0D 0A                 FCB    CR,LF
0C52   46 20 3D 20 50        FCC    "F = PORT A TEST"
0C57   4F 52 54 20 41
0C5C   20 54 45 53 54
0C61   0D 0A 03              FCB    CR,LF,ETX

                             PAG
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                              ****************************************************************
                              *                         MONITOR MENU AND MESSAGES
                              *

0C64    0D 0A 0D 0A     MENU     FCB      CR,LF,CR,LF
0C68    57 09 57 49 4E           FCC      "W      WINDINGS  (ON/OFF)"
0C6D    44 49 4E 47 53
0C72    20 20 28 4F 4E
0C77    2F 4F 46 46 29
0C7C    0D 0A                    FCB      CR,LF
0C7E    44 09 44 49 52           FCC      "D      DIRECTION  (CW/CCW)"
0C83    45 43 54 49 4F
0C88    4E 20 20 28 43
0C8D    57 2F 43 43 57
0C92    29
0C93    0D 0A 0D 0A              FCB      CR,LF,CR,LF
0C97    50 09 53 54 45           FCC      "P      STEP PULSE"
0C9C    50 20 50 55 4C
0CA1    53 45
0CA3    0D 0A                    FCB      CR,LF
0CA5    48 09 47 4F 20           FCC      "H      GO TO HOT LOAD"
0CAA    54 4F 20 48 4F
0CAF    54 20 4C 4F 41
0CB4    44
0CB5    0D 0A                    FCB      CR,LF
0CB7    43 09 47 4F 20           FCC      "C      GO TO COLD LOAD"
0CBC    54 4F 20 43 4F
0CC1    4C 44 20 4C 4F
0CC6    41 44
0CC8    0D 0A                    FCB      CR,LF
0CCA    52 09 52 45 54           FCC      "R      RETURN TO SCAN START POSITION"
0CCF    55 52 4E 20 54
0CD4    4F 20 53 43 41
0CD9    4E 20 53 54 41
0CDE    52 54 20 50 4F
0CE3    53 49 54 49 4F
0CE8    4E
0CE9    0D 0A                    FCB      CR,LF
0CEB    45 09 45 4E 43           FCC      "E      ENCODER POSITION"
0CF0    4F 44 45 52 20
0CF5    50 4F 53 49 54
0CFA    49 4F 4E
0CFD    0D 0A 0D 0A              FCB      CR,LF,CR,LF
0D01    49 09 49 4E 54           FCC      "I      INTEGRATE  (DUMP/INTEGRATE)"
0D06    45 47 52 41 54
0D0B    45 20 20 28 44
0D10    55 4D 50 2F 49
0D15    4E 54 45 47 52
0D1A    41 54 45 29
0D1E    0D 0A                    FCB      CR,LF
0D20    53 09 53 41 4D           FCC      "S      SAMPLE  (SAMPLE/HOLD)"
0D25    50 4C 45 20 20
0D2A    28 53 41 4D 50
0D2F    4C 45 2F 48 4F
0D34    4C 44 29
0D37    0D 0A                    FCB      CR,LF
                                 PAG
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1814  0D39  56 09 44 41 54            FCC     "V      DATA VALID  (LOW/HIGH)"
      0D3E  41 20 56 41 4C
      0D43  49 44 20 20 28
      0D48  4C 4F 57 2F 48
      0D4D  49 47 48 29
1815  0D51  0D 0A 0D 0A               FCB     CR,LF,CR,LF
1816  0D55  47 09 47 45 54            FCC     "G      GET DATA AT CURRENT POSITION"
      0D5A  20 44 41 54 41
      0D5F  20 41 54 20 43
      0D64  55 52 52 45 4E
      0D69  54 20 50 4F 53
      0D6E  49 54 49 4F 4E
1817  0D73  0D 0A                     FCB     CR,LF
1818  0D75  4E 09 4E 45 57            FCC     "N      NEW # SCANS PER CALIBRATE: 0-F (HEX)"
      0D7A  20 23 20 53 43
      0D7F  41 4E 53 20 50
      0D84  45 52 20 43 41
      0D89  4C 49 42 52 41
      0D8E  54 45 3A 20 30
      0D93  2D 46 20 28 48
      0D98  45 58 29
1819  0D9B  0D 0A                     FCB     CR,LF
1820  0D9D  41 09 41 43 51            FCC     "A      ACQUIRE DATA FOR ONE SCAN/CALIBRATE CYCLE"
      0DA2  55 49 52 45 20
      0DA7  44 41 54 41 20
      0DAC  46 4F 52 20 4F
      0DB1  4E 45 20 53 43
      0DB6  41 4E 2F 43 41
      0DBB  4C 49 42 52 41
      0DC0  54 45 20 43 59
      0DC5  43 4C 45
1821  0DC8  0D 0A 0D 0A               FCB     CR,LF,CR,LF
1822  0DCC  4C 09 4C 49 53            FCC     "L      LIST CURRENT AMPR STATUS"
      0DD1  54 20 43 55 52
      0DD6  52 45 4E 54 20
      0DDB  41 4D 50 52 20
      0DE0  53 54 41 54 55
      0DE5  53
1823  0DE6  0D 0A                     FCB     CR,LF
1824  0DE8  4D 09 45 58 49            FCC     "M      EXIT MODE: 0-F (HEX)"
      0DED  54 20 4D 4F 44
      0DF2  45 3A 20 30 2D
      0DF7  46 20 28 48 45
      0DFC  58 29
1825  0DFE  0D 0A                     FCB     CR,LF
1826  0E00  58 09 45 58 49            FCC     "X      EXIT TO NEXT MODE"
      0E05  54 20 54 4F 20
      0E0A  4E 45 58 54 20
      0E0F  4D 4F 44 45
1827  0E13  0D 0A                     FCB     CR,LF
1828  0E15  3F 09 4D 4F 4E     HELP   FCC     "?      MONITOR COMMAND MENU"
      0E1A  49 54 4F 52 20
      0E1F  43 4F 4D 4D 41
      0E24  4E 44 20 4D 45
      0E29  4E 55
1829  0E2B  0D 0A                     FCB     CR,LF
1830                                  PAG
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0E2D   0D 0A           PROMPT  FCB   CR,LF
0E2F   57 2C 44 2C 50          FCC   "W,D,P,H,C,R,I,S,V,G,N,A,L,M,X,?  ==> "
0E34   2C 48 2C 43 2C
0E39   52 2C 49 2C 53
0E3E   2C 56 2C 47 2C
0E43   4E 2C 41 2C 4C
0E48   2C 4D 2C 58 2C
0E4D   3F 20 20 3D 3D
0E52   3E 20
0E54   03                      FCB   ETX     END OF MENU
0E55   0D 0A 0D 0A     CV      FCB   CR,LF,CR,LF
0E59   53 54 41 54 55          FCC   "STATUS: "
0E5E   53 3A 20
0E61   28 56 34 2E 30  VER     FCC   "(V4.05)"
0E66   35 29
0E68   0D 0A           NL2MSG  FCB   CR,LF
0E6A   0D 0A 03        NLMSG   FCB   CR,LF,ETX
0E6D   53 41 4D 50 4C  SMSG    FCC   "SAMPLE"
0E72   45
0E73   0D 0A 03                FCB   CR,LF,ETX
0E76   48 4F 4C 44     HMSG    FCC   "HOLD"
0E7A   0D 0A 03                FCB   CR,LF,ETX
0E7D   49 4E 54 45 47  IMSG    FCC   "INTEGRATE"
0E82   52 41 54 45
0E86   0D 0A 03                FCB   CR,LF,ETX
0E89   44 55 4D 50     DMSG    FCC   "DUMP"
0E8D   0D 0A 03                FCB   CR,LF,ETX
0E90   57 49 4E 44 49  WBMSG   FCC   "WINDINGS O"
0E95   4E 47 53 20 4F
0E9A   03                      FCB   ETX
0E9B   4E              WNMSG   FCC   "N"
0E9C   0D 0A 03                FCB   CR,LF,ETX
0E9F   46 46           WFMSG   FCC   "FF"
0EA1   0D 0A 03                FCB   CR,LF,ETX
0EA4   43 4F 55 4E 54  CCWMSG  FCC   "COUNTER"
0EA9   45 52
0EAB   43 4C 4F 43 4B  CWMSG   FCC   "CLOCKWISE"
0EB0   57 49 53 45
0EB4   0D 0A 03                FCB   CR,LF,ETX
0EB7   44 41 54 41 20  VBMSG   FCC   "DATA VALID="
0EBC   56 41 4C 49 44
0EC1   3D
0EC2   03                      FCB   ETX
0EC3   4C 4F 57        NVMSG   FCC   "LOW"
0EC6   0D 0A 03                FCB   CR,LF,ETX
0EC9   48 49 47 48     VMSG    FCC   "HIGH"
0ECD   0D 0A 03                FCB   CR,LF,ETX
0ED0   3F              NPMSG   FCC   "?"
0ED1   20 3D 20 4D 4F  POSMSG  FCC   " = MOTOR POSITION"
0ED6   54 4F 52 20 50
0EDB   4F 53 49 54 49
0EE0   4F 4E
0EE2   0D 0A 03                FCB   CR,LF,ETX
0EE5   20 3D 20 45 58  XMSG    FCC   " = EXIT MODE"
0EEA   49 54 20 4D 4F
0EEF   44 45
0EF1   0D 0A 03                FCB   CR,LF,ETX
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0EF4   20 49 53 20 23   SPCMSG  FCC     " IS # SCANS/CALIBRATE"
0EF9   20 53 43 41 4E
0EFE   53 2F 43 41 4C
0F03   49 42 52 41 54
0F08   45
0F09   0D 0A 03                 FCB     CR,LF,ETX
0F0C   48 4F 54 20 4C   HLMSG   FCC     "HOT LOAD; "
0F11   4F 41 44 3B 20
0F16   03                       FCB     ETX
0F17   43 4F 4C 44 20   CLMSG   FCC     "COLD LOAD; "
0F1C   4C 4F 41 44 3B
0F21   20
0F22   03                       FCB     ETX
0F23   49 4E 44 45 58   NXMSG   FCC     "INDEX; "
0F28   3B 20
0F2A   03                       FCB     ETX
0F2B   0D 0A            HXMSG   FCB     CR,LF
0F2D   4E 45 57 20 56           FCC     "NEW VALUE (HEX: 0-F) ==> "
0F32   41 4C 55 45 20
0F37   28 48 45 58 3A
0F3C   20 30 2D 46 29
0F41   20 3D 3D 3E 20
0F46   03                       FCB     ETX
0F47   50 52 45 53 53   KPMSG   FCC     "PRESS A KEY"
0F4C   20 41 20 4B 45
0F51   59
0F52   0D 0A 03                 FCB     CR,LF,ETX
0F55   44 54 52 20 4E   HEYYOU  FCC     "DTR NOT DETECTED.  PRESS RETURN IF RS-232 IS ATTACHED."
0F5A   4F 54 20 44 45
0F5F   54 45 43 54 45
0F64   44 2E 20 20 50
0F69   52 45 53 53 20
0F6E   52 45 54 55 52
0F73   4E 20 49 46 20
0F78   52 53 2D 32 33
0F7D   32 20 49 53 20
0F82   41 54 54 41 43
0F87   48 45 44 2E
0F8B   0D 0A 07 03              FCB     CR,LF,BEL,ETX
                                PAG
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                          ****************************************************************
                          *                        COPYRIGHT

0F8F   28 43 29 31 39     AUTHOR  FCC     "(C)1989, 1990   MICHAEL L. BLYLER"
0F94   38 39 2C 20 31
0F99   39 39 30 20 20
0F9E   20 4D 49 43 48
0FA3   41 45 4C 20 4C
0FA8   2E 20 42 4C 59
0FAD   4C 45 52
0FB0   20 47 45 4F 52             FCC     " GEORGIA TECH RESEARCH INSTITUTE "
0FB5   47 49 41 20 54
0FBA   45 43 48 20 52
0FBF   45 53 45 41 52
0FC4   43 48 20 49 4E
0FC9   53 54 49 54 55
0FCE   54 45 20
0FD1   56 45 52 53 49             FCC     "VERSION 4.06 4/30/90"
0FD6   4F 4E 20 34 2E
0FDB   30 36 20 34 2F
0FE0   33 30 2F 39 30

                          ****************************************************************
                          *                        OPTION REGISTER
                          *

1FDF                              ORG     OPTION          SECURITY FEATURE ENABLED

1FDF   00                         FCB     $00

                          ****************************************************************
                          *                        VECTORS
                          *
1FF4                              ORG     VECTOR

1FF4   0B47                       FDB     SPIRQ
1FF6   0B48                       FDB     SCIRQ
1FF8   0B51                       FDB     TIRQ
1FFA   0B4A                       FDB     IRQ
1FFC   0B49                       FDB     SWI
1FFE   045E                       FDB     RESET           RESET/POWER UP
2000                              END
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Defined	Symbol Name	Value	References										
177	A1	0060	845	873									
178	A2	0061	1553	1574									
179	A3	0062											
180	A4	0063											
1588	ACQ	0AD8	492	1267	1270								
1590	ACQL	0ADC	1596										
166	ALOOP	0055	1589	1595									
43	ALTH	= 001A	1422	1440	1669								
44	ALTL	= 001B	1427	1443	1685								
489	ASUB	055E	281	944									
496	ASUB1	0567	945										
501	ASUB2	0572	498										
1886	AUTHOR	0F8F											
65	AWO	= 0003	336	419	632	828	829	832	1470	1471			
30	BAUD	= 000D	350										
138	BEL	= 0007	1881										
1265	CAL	091C	505	1102									
67	CCW	= 0002	532	533	638	1290	1350	1513					
1853	CCWMSG	0EA4	534	642									
1871	CLMSG	0F17	693										
Pre	CODE	0050	147	159	190	220	247	274	1894	1901			
523	COLD	0590	520										
47	COPCR	= 001E	387	389									
46	COPRR	= 001D	1234	1236	1436	1438	1484	1486	1592	1594	1737	1739	
135	CR	= 000D	432	1752	1752	1754	1754	1756	1758	1760	1762	1764	1766
			1768	1770	1773	1775	1777	1779	1781	1783	1785	1787	1794
			1794	1796	1798	1798	1800	1802	1804	1806	1808	1808	1810
			1812	1815	1815	1817	1819	1821	1821	1823	1825	1827	1829
			1831	1834	1834	1837	1838	1840	1842	1844	1846	1850	1852
			1855	1859	1861	1864	1866	1868	1875	1879	1881		
518	CS1	0586	516										
515	CSUB	057F	282	1268									
224	CTABLE	0200											
923	CUR1	07A3	923										
927	CUR10	07AB	922										
920	CURSUB	079C	535	538	552	616	619	629	631	634	637	640	643
			646	649	652	655	657	660	663	667	671	685	689
			694	699	703	722	739	795	798	809	813	816	827
			831	835	926	1142	1720						
1834	CV	0E55	534	537	551	615	618	630	633	636	639	642	645
			648	651	654	656	659	662	666	670	684	688	693
			698	702	721	738	794	797	808	812	815	826	830
			834	920	1141	1719							
66	CW	= 0002	335	536	781	1254	1288	1347	1348	1510	1518	1531	1612
1854	CWMSG	0EAB	537	639									
Pre	DATA	0000											
536	DCW	059B	532										
26	DDRA	= 0004	327										
27	DDRB	= 0005	328										
28	DDRC	= 0006	329										
174	DEST	005D	1293	1315	1330	1343	1374	1400					
617	DMP	05FC	613										
1845	DMSG	0E89	618	645									
532	DSUB	0591	283										
86	DTR	= 0007	420										
64	DUMP	= 0004	338	463	585	617	1237						
164	EOS	0053	359	1240									

Defined	Symbol Name	Value	References										
45	EPROG	= 001C											
139	ESC	= 001B	1106										
548	ESUB	05A2	284	553									
137	ETX	= 0003	424	441	476	715	921	1787	1833	1838	1840	1842	1844
			1846	1848	1850	1852	1855	1857	1859	1861	1864	1866	1868
			1870	1872	1874	1877	1879	1881					
173	FLAG	005C	331	332	333	334	498	956	967	978	989	1000	1011
			1022	1035	1036	1047	1048	1059	1060	1071	1072	1249	1304
			1307	1309	1555	1562	1616	1742					
197	FTABLE	0100											
175	FUDGE	005E	1505	1515	1517								
1553	GETPOS	0AB0	548	775	1145	1149	1238	1353	1489	1506			
1555	GP0	0AB4	1562										
1571	GP1	0AD0	1567	1569									
170	GSTEP	0059	1094	1096									
565	GSUB	05B5	285	1095	1166	1590							
69	HBYTE	= 0000	342	1561									
41	HCOUNT	= 0018											
905	HECHO	0796	897	905									
1828	HELP	0E15											
898	HEX2	0789	895										
888	HEXIN	0775	723	740	888	893	900	902					
1880	HEYYOU	0F55	423										
186	HFETCH	006C	364	366	370	374	496	499	503	1429			
796	HLD	0705	792										
1869	HLMSG	0F0C	698										
1841	HMSG	0E76	651	797									
62	HOLD	= 0005	340	462	583	796	1231						
603	HOT	05F1	600										
128	HS	= 0006	334	498	1036	1048	1060	1072					
598	HS1	05E7	596										
595	HSUB	05E0	286	1265									
1875	HXMSG	0F2B	721	738									
107	ICF	= 0007	1614	1740									
99	ICIE	= 0007	1608	1621									
37	ICRH	= 0014											
38	ICRL	= 0015	1610	1615	1741								
102	IEDG	= 0001	1611	1620	1743	1744	1746						
1843	IMSG	0E7D	615	648									
127	INDEX	= 0007	331	1555	1562	1616	1742						
63	INT	= 0004	565	613	614	644	1185						
1719	IRQ	0B4A	1906										
1721	IRQ1	0B4F	1721										
123	IRQL	= 0001											
613	ISUB	05F2	287										
280	JTABLE	0400	472										
1878	KPMSG	0F47	1141										
422	L0	04E6	422	428									
429	L00	04F5	425	429									
435	L1	0501	439										
436	L11	0504	436										
440	L12	050C	446										
443	L13	0513	443										
447	L2	051B	442	447	477								
466	L25	0540	454										
474	L3	054F	474	480									
70	LBYTE	= 0000	1558										

Defined	Symbol Name		Value	References										
42	LCOUNT	=	0019	1735										
638	LD		061B	635										
642	LDCCW		0625	638										
136	LF	=	000A	1752	1752	1754	1754	1756	1758	1760	1762	1764	1766	1768
				1770	1773	1775	1777	1779	1781	1783	1785	1787	1794	1794
				1796	1798	1798	1800	1802	1804	1806	1808	1808	1810	1812
				1815	1815	1817	1819	1821	1821	1823	1825	1827	1829	1831
				1834	1834	1837	1838	1840	1842	1844	1846	1850	1852	1855
				1859	1861	1864	1866	1868	1875	1879	1881			
185	LFETCH		0068	363	368	371	373	497	500	504	1426			
644	LI		062A	641										
648	LINT		0634	644										
664	LN		065C	661										
682	LPOS		0670	756										
686	LPOS0		0679	683										
691	LPOS1		0684	687										
696	LPOS2		068F	692										
700	LPOS3		0698	690	695	697								
650	LS		0639	647										
654	LSS		0643	650										
628	LSUB		0603	288										
656	LV		0648	653										
662	LVAL		0657	658										
630	LW		0607											
636	LWF		0616	632										
668	LX		0666											
1087	M12A		0824	1107										
1092	M12B		082D	1101										
1095	M12C		0833	1097										
1141	M14		0867	1153										
1143	M14A		086C	1143										
1166	M15		0887	1168										
1794	MENU		0C64	435	440									
419	MODE0		04E0	301	433	1108								
954	MODE1		07B6	302										
1057	MODE10		080B	311										
1069	MODE11		0816	312										
1086	MODE12		0821	313	1103									
1117	MODE13		0852	314	1125									
1140	MODE14		0864	315										
1165	MODE15		0885	316										
965	MODE2		07BF	303										
976	MODE3		07C8	304										
987	MODE4		07D1	305										
998	MODE5		07DA	306										
1009	MODE6		07E3	307										
1020	MODE7		07EC	308										
1033	MODE8		07F5	309										
1045	MODE9		0800	310										
1752	MODES		0B70	714										
434	MON		0500	420	451	467	469							
1288	MOVE		0930	522	602	778	1089	1148	1152	1253				
172	MPREV		005B	1301	1318	1320	1333	1335	1376	1403	1405			
714	MS1		06A3	720										
717	MS2		06AA	717										
721	MS3		06B2	716										
171	MSC		005A	330	1310	1313	1325	1328	1369	1372	1377	1395	1398	1406

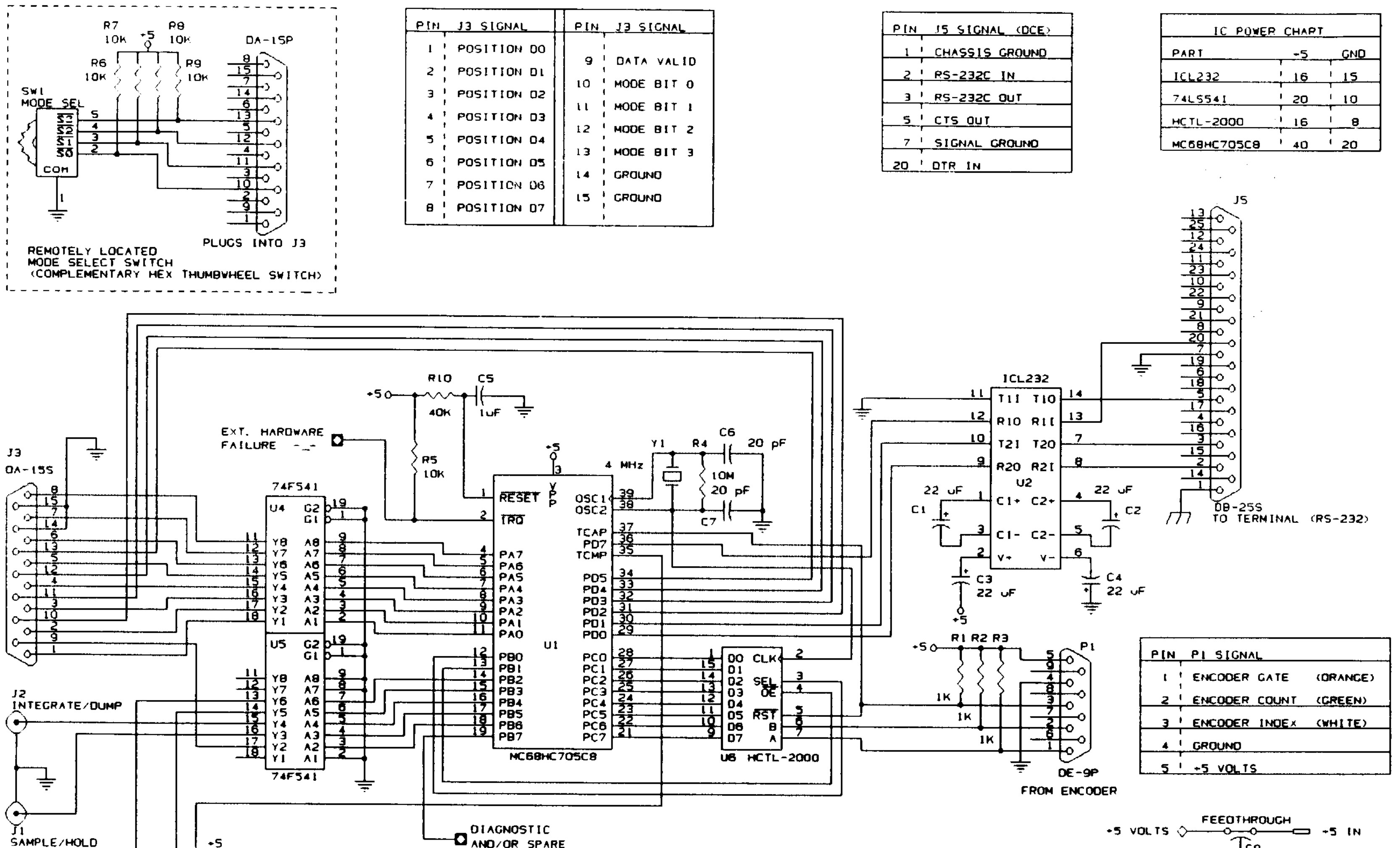
Defined	Symbol Name	Value	References
			1474 1481
945	MSL1	07B1	946
943	MSLOOP	07AC	957 968 979 990 1001 1012 1023 1037 1049 1061 1073
169	MSTEP	0058	361 752 755 1475
713	MSUB	06A2	289
301	MTABLE	042E	391 465
1291	MV0	0936	1289
1298	MV1	0945	1295
1342	MV10	09A2	1340
1343	MV11	09A5	1322 1352
1347	MV12	09AE	1319 1334
1350	MV13	09B5	1347
1351	MV14	09B7	1346 1349
1353	MV15	09BC	1317 1332 1345
1301	MV2	094C	1299
1308	MV3	0959	1306
1311	MV4	0961	1314
1315	MV5	0969	1309
1323	MV6	097B	1297 1303
1325	MV7	0980	1338
1326	MV8	0982	1329
1341	MV9	09A0	1337
1837	NL2MSG	0E68	
1838	NLMSG	0E6A	551
1533	NP1	0AA1	1531
1537	NP2	0AA9	1534
1540	NP3	0AAF	1536 1538
1862	NPMSG	0ED0	684
1530	NPOS	0A9B	
1513	NS2	0A8B	1509
1515	NS3	0A90	1512
1516	NS4	0A92	1510 1513
1520	NS5	0A9A	1508 1518
1504	NSTEP	0A77	1294 1316 1331 1344 1375 1401
738	NSUB	06BD	290
744	NSUB1	06CA	742
814	NV	071B	810
60	NVAL	= 0006	339 464 578 814 1220
1858	NVMSG	0EC3	659 815
1873	NXMSG	0F23	688
108	OCF	= 0006	1439 1452 1693
100	OCIE	= 0006	
39	OCRH	= 0016	1423 1430 1431 1441 1446 1448 1670 1688 1689
40	OCRL	= 0017	1434 1451 1692
129	ODD	= 0001	332 1304 1307 1309
68	OE	= 0001	343 1556 1560
149	OFFSET	0020	471
103	OLVL	= 0000	1425 1442 1671 1673
116	OPTION	= 1FDF	325 1894
845	OUT3	073B	550 665 669 701
848	OUT31	0741	852
853	OUT32	074A	849
855	OUT33	074E	855
858	OUT34	0755	854 862
863	OUT35	075E	859
867	OUT36	0764	867
869	OUT37	0769	864 869

Defined	Symbol Name		Value	References
Pre	PAGE0		0000	
22	PORTA	=	0000	352 461 779 1090 1120 1124 1165 1167 1242 1292 1355
				1588 1619
23	PORTB	=	0001	335 336 338 339 340 341 342 343 419 462 463
				464 532 533 536 565 578 579 583 584 585 613
				614 617 632 638 644 650 658 781 792 793 796
				810 811 814 828 829 832 1185 1186 1220 1221 1231
				1232 1237 1252 1254 1288 1290 1347 1348 1350 1470 1471
				1510 1513 1518 1531 1556 1558 1560 1561 1612
24	PORTC	=	0002	1557 1559
25	PORTD	=	0003	380 420
161	POS		0050	353 460 515 519 549 595 599 682 700 768 776
				1146 1150 1239 1354 1487 1490 1507 1533 1572 1618
1863	POSMSG		0ED1	702
1831	PROMPT		0E2D	475
751	PSUB		06CD	291
1636	PULSE		0B0A	337 833 1472 1473
772	R1		06E4	769
774	R2		06E8	
779	R3		06F4	773
780	R4		06F6	771
114	RAM	=	0050	159
121	RAM0	=	0007	
122	RAM1	=	0006	
1392	RAMPDN		09E2	1321 1342
1366	RAMPUP		09C4	1308 1324
1396	RD0		09E8	1409
1400	RD1		09EF	
1407	RD2		09FE	1399
1412	RD3		0A05	1402 1404
95	RDRF	=	0005	429 447 553 888 1103 1143
322	RESET		045E	1908
768	RETURN		06DB	292 489 517 597 1086 1140 1271
1426	RL0		0A0E	1424
1439	RL1		0A27	1439
1452	RL2		0A42	1452
176	RLEN		005F	1368 1380
1422	RLOOP		0A06	1312 1327 1371 1397 1411
115	ROM	=	0100	190 220 247 274
130	RT	=	0000	333 956 967 978 989 1000 1011 1022 1035 1047 1059
				1071
168	RTEMP		0057	1428 1433 1445 1450
1370	RU0		09CB	1381
1374	RU1		09D2	
1378	RU2		09DB	1373
1382	RU3		09E1	
1185	SCAN		088E	501 1243
1242	SCAN1		0900	1255
1244	SCAN2		0904	1241
1256	SCAN3		091B	1247
162	SCANS		0051	357 664 744 955 966 977 988 999 1010 1021 1034
				1046 1058 1070 1100 1246
163	SCANUM		0052	780 1092 1098 1244 1248
31	SCCR1	=	000E	346
32	SCCR2	=	000F	348
34	SCI	=	0011	426 430 437 444 448 478 554 718 856 868 871
				889 906 924 1104 1144

Defined	Symbol Name	Value	References
1702	SCIRQ	0B48	1904
33	SCSR	= 0010	422 429 436 443 447 474 553 717 855 867 869
			888 905 923 1103 1143
61	SMPL	= 0005	579 650 792 793 1221
1839	SMSG	0E6D	654 794
1867	SPCMSG	0EF4	666
29	SPCR	= 000A	344
1701	SPIRQ	0B47	1903
792	SSUB	06FB	293
1473	ST0	0A50	1470
1475	ST1	0A55	1482
1491	ST2	0A74	1488
251	STABLE	0300	
1469	STEP	0A46	753 1300 1351 1613
1703	SWI	0B49	1907
1608	SYNC	0AEB	770
1613	SYNC1	0AF5	1614
35	TCR	= 0012	376 943 1425 1442 1608 1611 1620 1621 1671 1673 1733
			1743 1744 1746
94	TDRE	= 0007	422 436 443 474 717 855 867 869 905 923
58	TEST	= 0007	341 1186 1252
1740	TI0	0B60	1733 1734
1746	TI1	0B6D	1743
1747	TI2	0B6F	1740
1733	TIRQ	0B51	1905
109	TOF	= 0005	1734
101	TOIE	= 0005	943 1733
36	TSR	= 0013	1432 1439 1449 1452 1609 1614 1690 1693 1734 1740
59	VAL	= 0006	584 658 810 811 1232
1856	VBMSG	0EB7	656 808
117	VECTOR	= 1FF4	1901
1836	VER	0E61	1719
1860	VMSG	0EC9	662 812
808	VSUB	070C	294
1668	WAIT	0B17	379 568 571 574 577 582 1119 1123 1189 1192 1195
			1198 1201 1204 1207 1210 1213 1216 1219 1224 1227 1230
			1477 1480 1638 1641
1674	WAIT0	0B22	1672
1679	WAIT1	0B2A	1675
1685	WAIT2	0B33	1678 1682
1693	WAIT3	0B42	1693
1847	WBMSG	0E90	630 826
1851	WFMSG	0E9F	636 830
1849	WNMSG	0E9B	633 834
832	WON	0731	828
826	WSUB	0722	295
167	WTEMP	0056	1686 1691
181	X1	0064	846 872
182	X2	0065	1554 1573
183	X3	0066	1504 1516
184	X4	0067	1469 1491
165	XMODE	0054	355 455 668 724
1865	XMSG	0EE5	670
113	ZROM	= 0020	147

APPENDIX B

AMPR ELECTRONIC MODULE SCHEMATIC DIAGRAMS



PIN	J3 SIGNAL
1	POSITION D0
2	POSITION D1
3	POSITION D2
4	POSITION D3
5	POSITION D4
6	POSITION D5
7	POSITION D6
8	POSITION D7

PIN	J3 SIGNAL
9	DATA VALID
10	MODE BIT 0
11	MODE BIT 1
12	MODE BIT 2
13	MODE BIT 3
14	GROUND
15	GROUND

PIN	J5 SIGNAL (DCE)
1	CHASSIS GROUND
2	RS-232C IN
3	RS-232C OUT
5	CTS OUT
7	SIGNAL GROUND
20	DTR IN

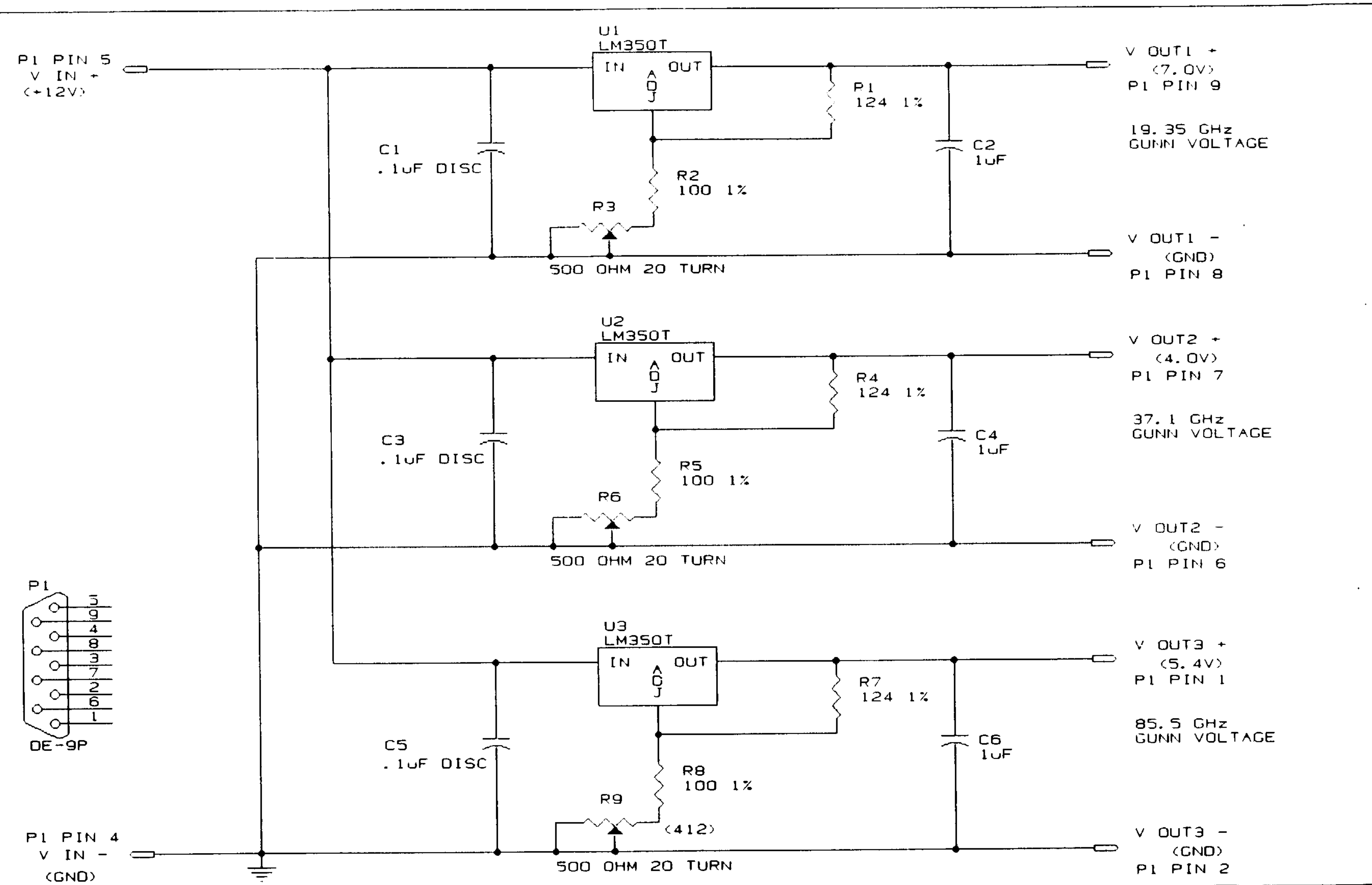
IC POWER CHART

PART	-5	GND
ICL232	16	15
74LS541	20	10
HCTL-2000	16	8
MC68HC705C8	40	20

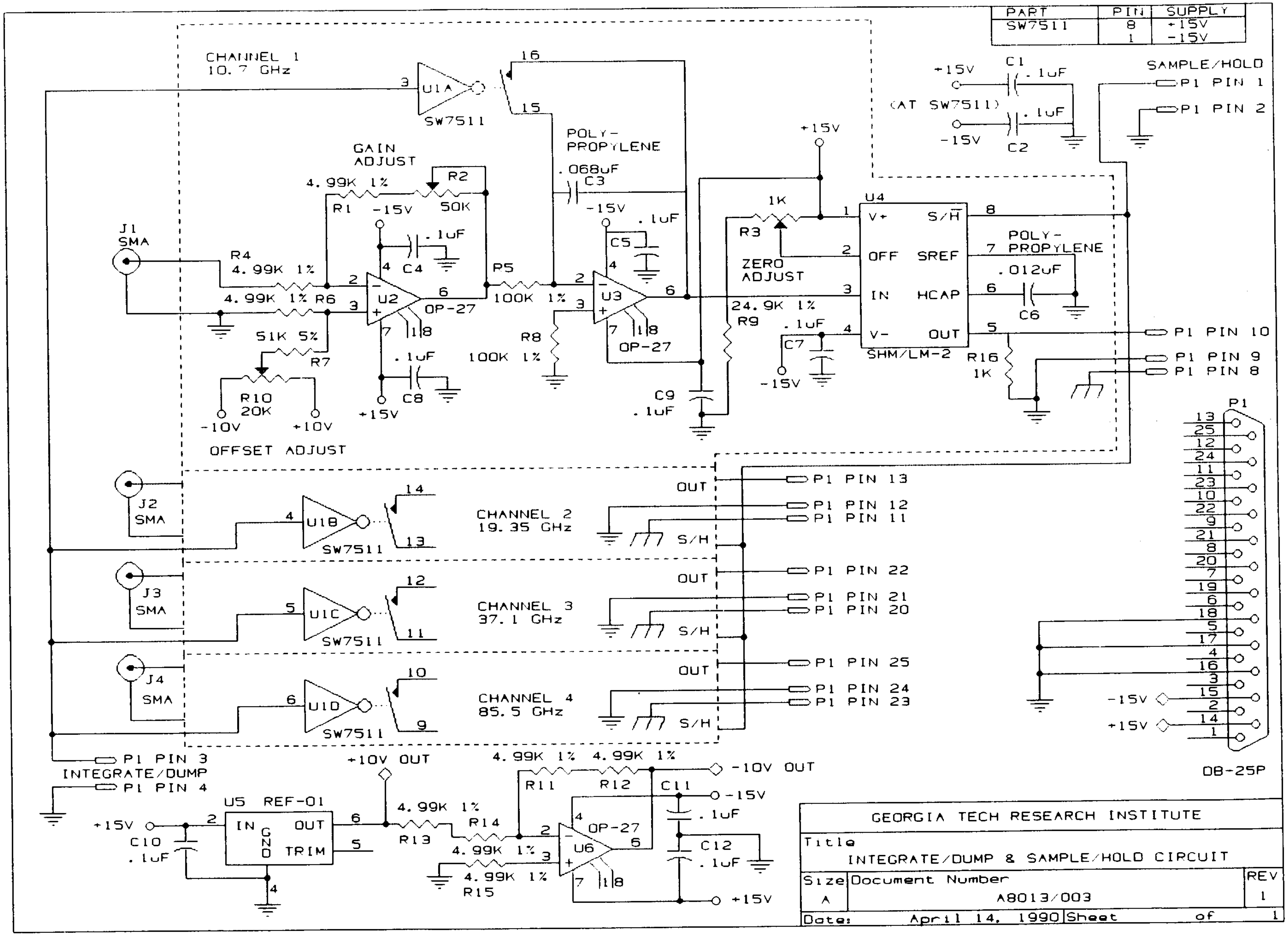
PIN	P1 SIGNAL
1	ENCODER GATE (ORANGE)
2	ENCODER COUNT (GREEN)
3	ENCODER INDEX (WHITE)
4	GROUND
5	+5 VOLTS

PIN	J4 SIGNAL
1	DIRECTION (CW/CCW)
2	GROUND
3	ALL WINDINGS OFF
4	STEP PULSE
5	+5 VOLTS

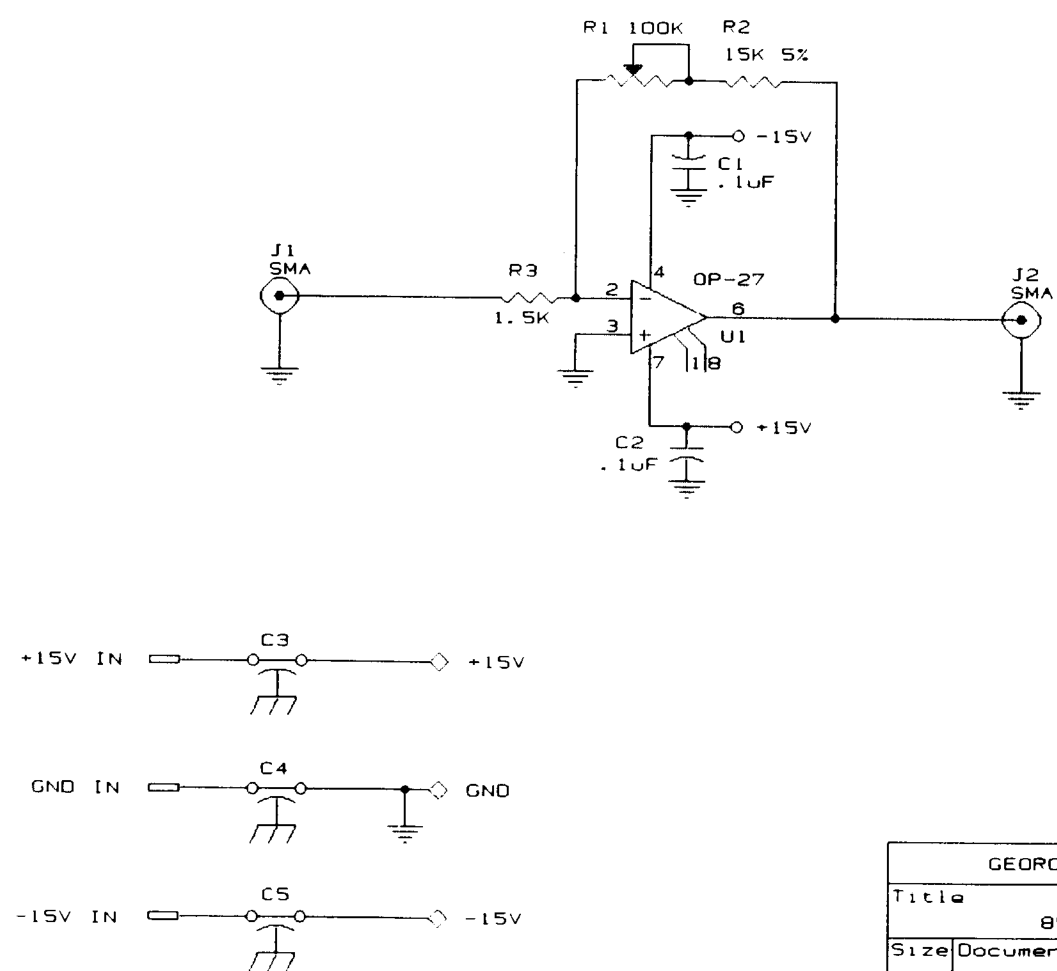
GEORGIA TECH RESEARCH INSTITUTE		
Title: AMPR SCANNER PROCESSOR		
Size: B	Document Number: A8013/001	REV: 1
Date: April 19, 1990	Sheet 1 of 1	



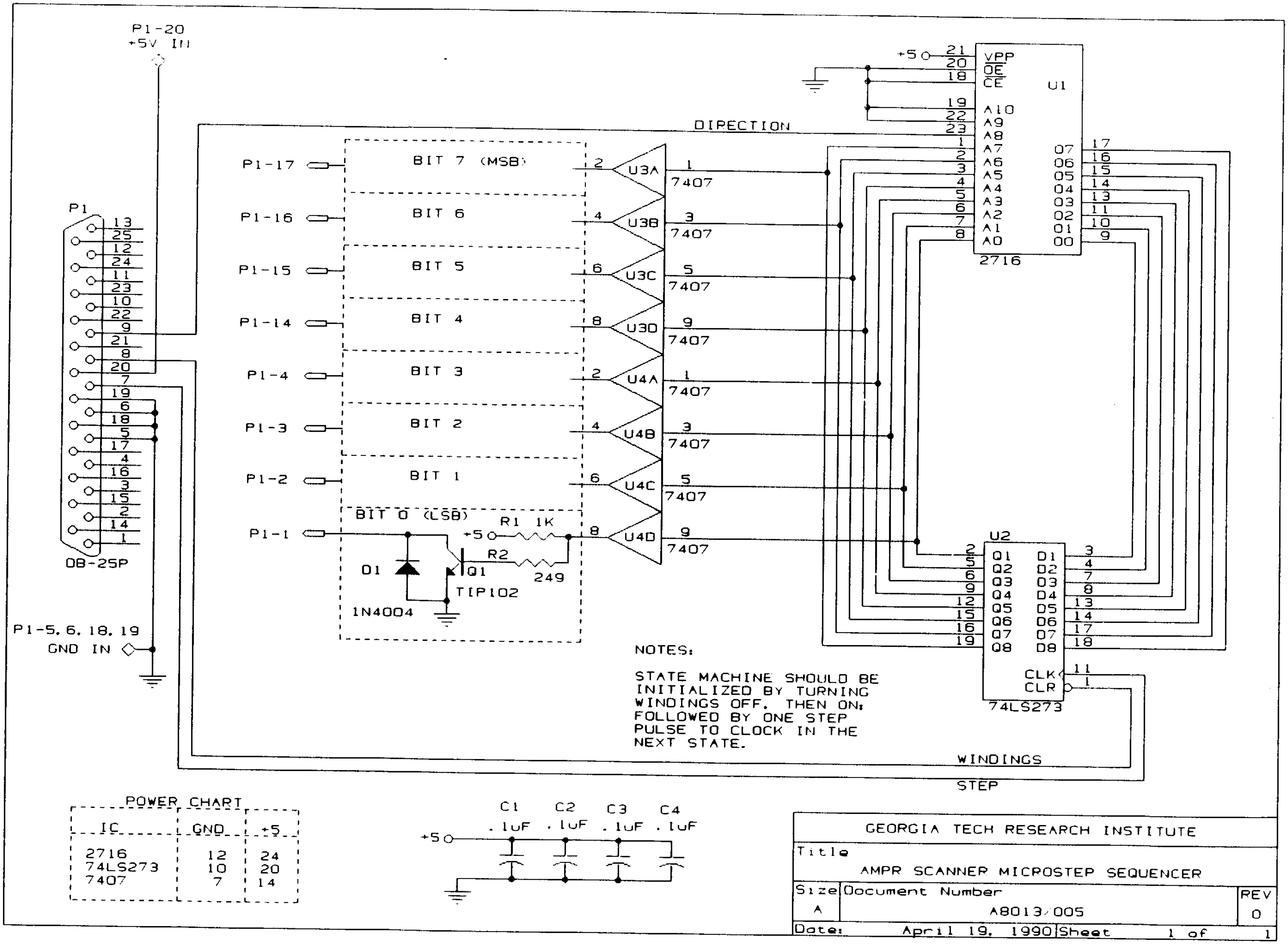
GEORGIA TECH RESEARCH INSTITUTE		
Title GUNN DIODE OSCILLATOR POWER SUPPLY PEGULATOR		
Size A	Document Number A8013/002	REV 0
Date: April 18, 1990	Sheet 1 of 1	

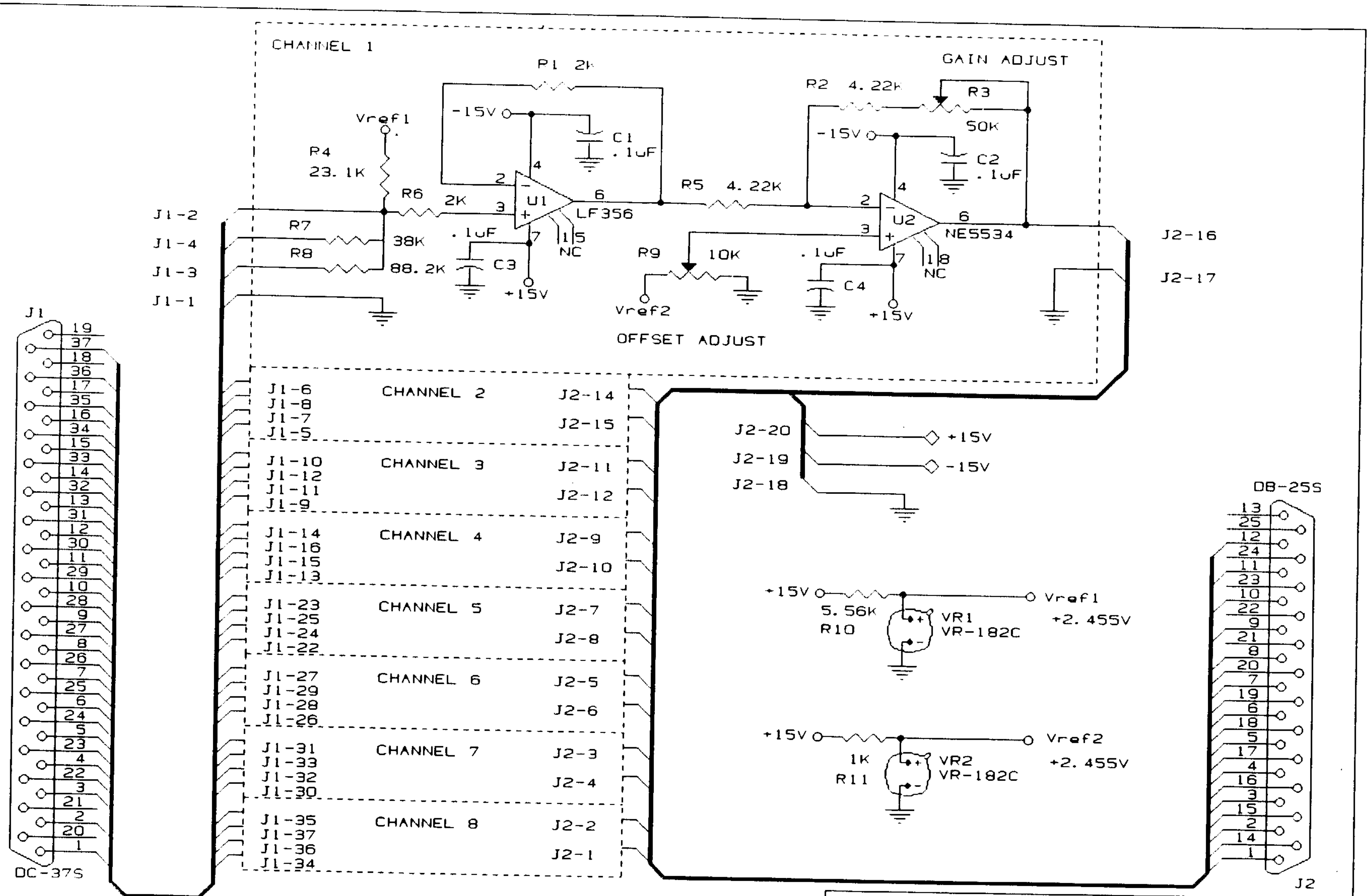


CHANNEL 1
10.7 GHz
U1A
SW7511
GAIN ADJUST
4.99K 1%
R1
R2
50K
J1
SMA
R4
4.99K 1%
4.99K 1% R6
U2
OP-27
P5
100K 1%
R8
100K 1%
51K 5%
R7
R10
20K
-10V
+10V
OFFSET ADJUST
POLY-PROPYLENE
.068uF
C3
U3
OP-27
C9
.1uF
24.9K 1%
R9
R3
1K
ZERO ADJUST
U4
V+
OFF
IN
V-
S/H
SREF
HCAP
OUT
SHM/LM-2
.012uF
C6
R16
1K
P1 PIN 10
P1 PIN 9
P1 PIN 8
SAMPLE/HOLD
P1 PIN 1
P1 PIN 2
PART | PIN | SUPPLY
SW7511 | 8 | +15V
1 | -15V
(AT SW7511)
C1
C2
J2
SMA
U1B
SW7511
CHANNEL 2
19.35 GHz
OUT
S/H
P1 PIN 13
P1 PIN 12
P1 PIN 11
J3
SMA
U1C
SW7511
CHANNEL 3
37.1 GHz
P1 PIN 22
P1 PIN 21
P1 PIN 20
J4
SMA
U1D
SW7511
CHANNEL 4
85.5 GHz
P1 PIN 25
P1 PIN 24
P1 PIN 23
P1
DB-25P
P1 PIN 3
INTEGRATE/DUMP
P1 PIN 4
U5 REF-01
IN
GND
OUT
TRIM
C10
.1uF
+10V OUT
-10V OUT
4.99K 1%
R11
R12
R13
R14
R15
U6
OP-27
C11
C12
GEORGIA TECH RESEARCH INSTITUTE
Title
INTEGRATE/DUMP & SAMPLE/HOLD CIRCUIT
Size A
Document Number A8013/003
REV 1
Date: April 14, 1990
Sheet 1 of 1

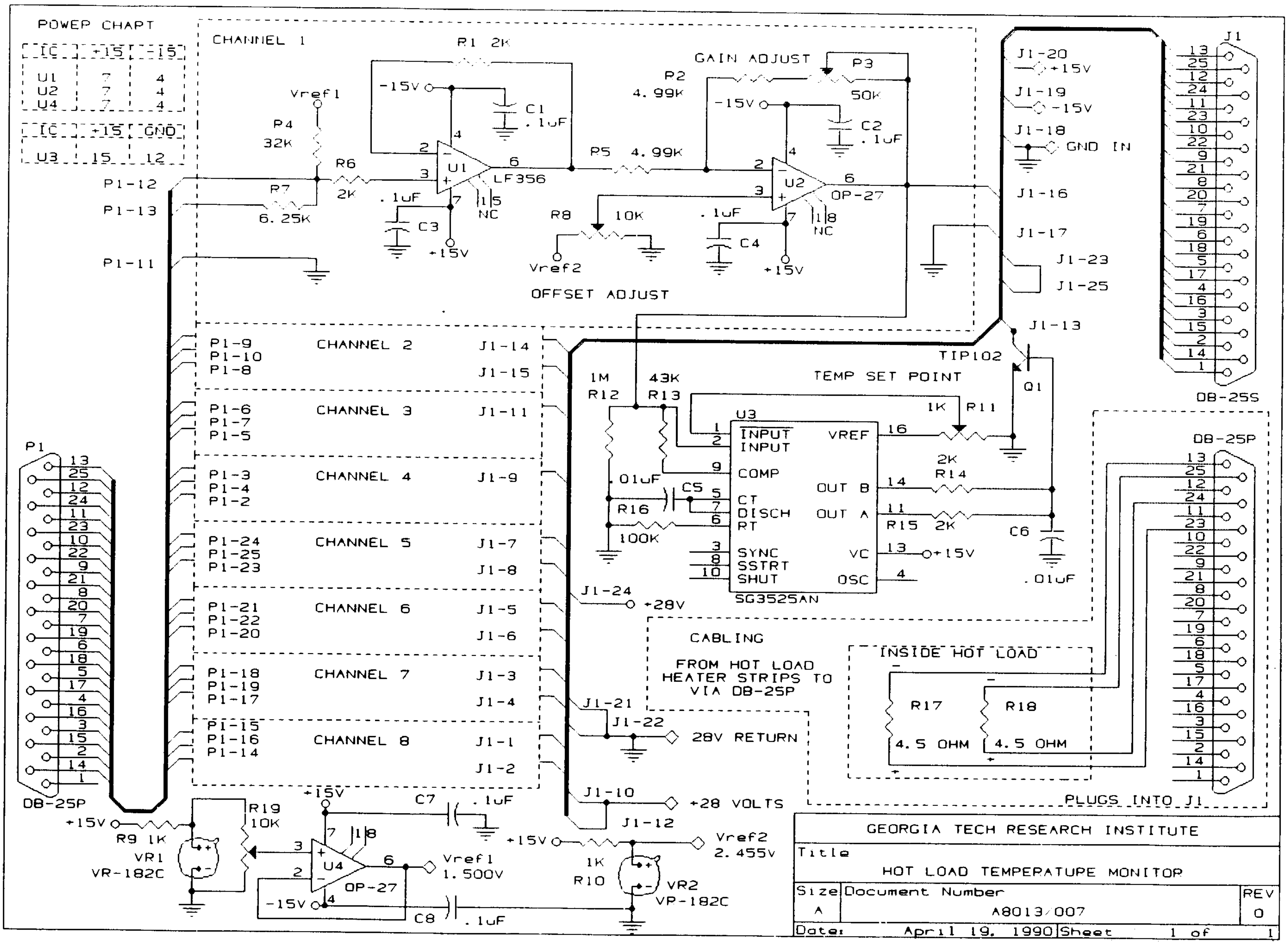


GEORGIA TECH RESEARCH INSTITUTE			
Title: 85.5 GHz VIDEO AMPLIFIER			
Size: A	Document Number: A8013·004		REV: 0
Date: April 19, 1990		Sheet 1 of 1	

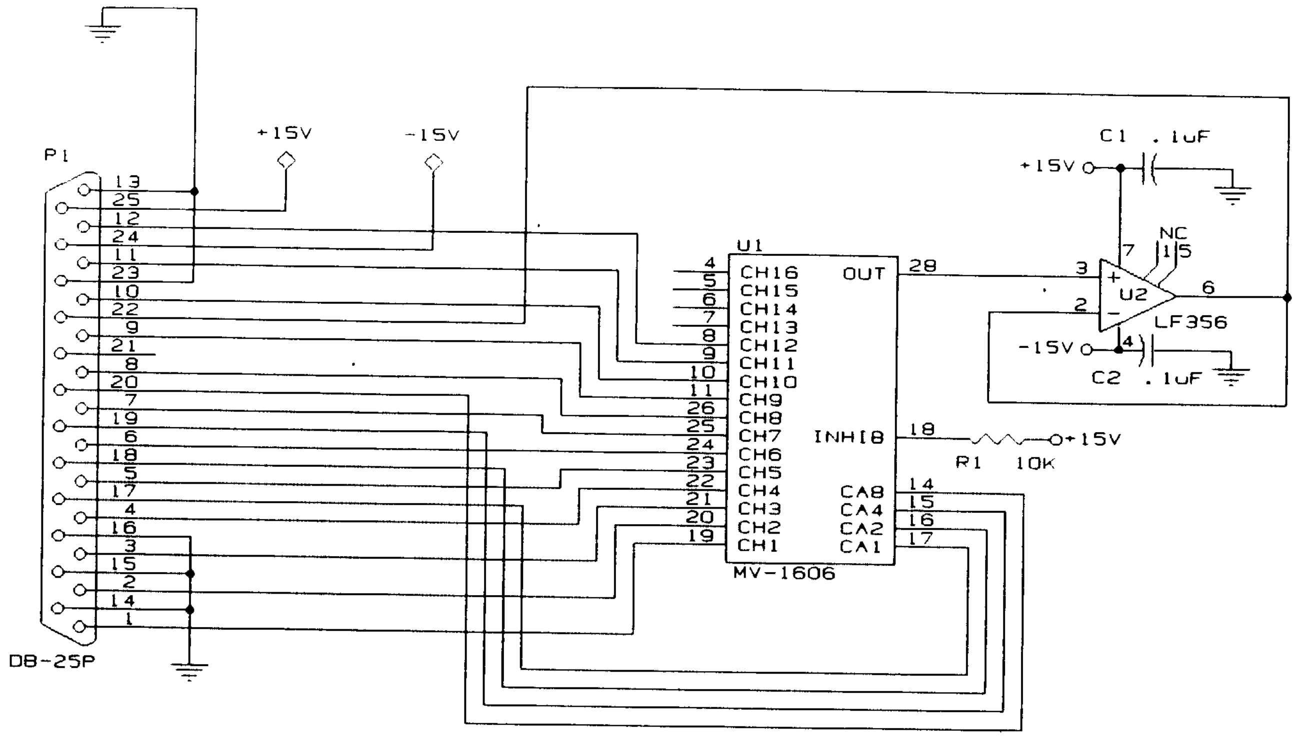

P1-20
+5V IN
P1
DB-25P
P1-5, 6, 18, 19
GND IN
DIRECTION
P1-17
P1-16
P1-15
P1-14
P1-4
P1-3
P1-2
P1-1
BIT 7 (MSB)
BIT 6
BIT 5
BIT 4
BIT 3
BIT 2
BIT 1
BIT 0 (LSB)
R1 1K
R2
249
+5
D1
1N4004
Q1
TIP102
U3A
U3B
U3C
U3D
U4A
U4B
U4C
U4D
7407
U1
2716
VPP
OE
CE
A10 A9 A8 A7 A6 A5 A4 A3 A2 A1 A0
O7 O6 O5 O4 O3 O2 O1 O0
U2
74LS273
Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8
D1 D2 D3 D4 D5 D6 D7 D8
CLK
CLR
WINDINGS
STEP
C1 C2 C3 C4
.1uF .1uF .1uF .1uF
NOTES:
STATE MACHINE SHOULD BE INITIALIZED BY TURNING WINDINGS OFF, THEN ON; FOLLOWED BY ONE STEP PULSE TO CLOCK IN THE NEXT STATE.
POWER CHART
IC GND +5
2716 12 24
74LS273 10 20
7407 7 14
GEORGIA TECH RESEARCH INSTITUTE
Title
AMPR SCANNER MICROSTEP SEQUENCER
Size A
Document Number A8013/005
REV 0
Date: April 19, 1990
Sheet 1 of 1



GEORGIA TECH RESEARCH INSTITUTE		
Title COLD LOAD TEMPERATURE MONITOR		
Size A	Document Number A8013 006	REV 0
Date: April 19, 1990	Sheet 1 of 1	



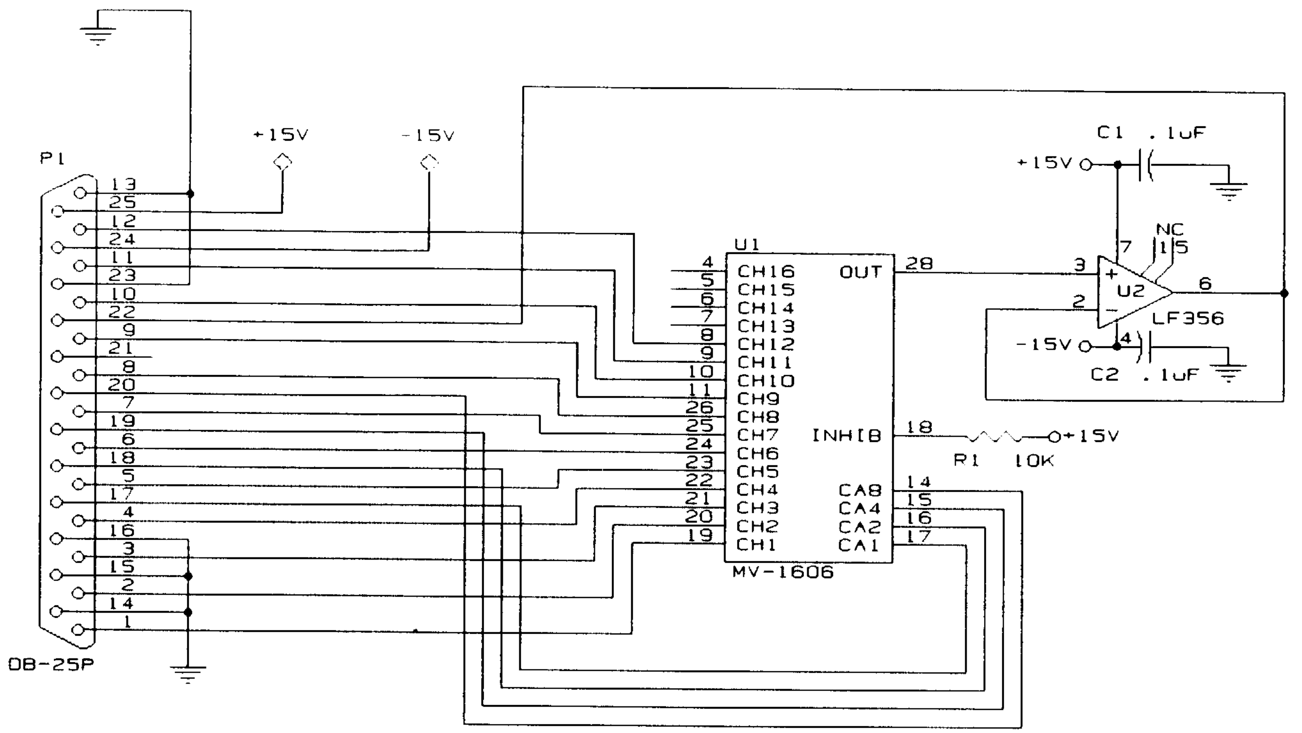
POWEP CHAPT
IC +15 -15
U1 7 4
U2 7 4
U4 7 4
IC +15 GND
U3 15 12
CHANNEL 1
R1 2K
Vref1
P4 32K
R6 2K
R7 6.25K
-15V
C1 .1uF
U1 LF356
NC
.1uF C3
+15V
P1-12
P1-13
P1-11
GAIN ADJUST
P2 4.99K
P3 50K
P5 4.99K
C2 .1uF
U2 OP-27
R8 10K
Vref2
OFFSET ADJUST
.1uF C4
J1-20 +15V
J1-19 -15V
J1-18 GND IN
J1-16
J1-17
J1-23
J1-25
J1-13
J1
DB-25S
TIP102
Q1
TEMP SET POINT
1K R11
CHANNEL 2
CHANNEL 3
CHANNEL 4
CHANNEL 5
CHANNEL 6
CHANNEL 7
CHANNEL 8
1M R12
43K R13
U3
INPUT
INPUT
COMP
CT
DISCH
RT
SYNC
SSTRT
SHUT
VREF
OUT B
OUT A
VC
OSC
SG3525AN
.01uF C5
R16 100K
2K R14
R15 2K
C6 .01uF
J1-24 +28V
CABLING
FROM HOT LOAD HEATER STRIPS TO VIA DB-25P
INSIDE HOT LOAD
R17 4.5 OHM
R18 4.5 OHM
J1-21
J1-22
28V RETURN
J1-10
+28 VOLTS
J1-12
PLUGS INTO J1
DB-25P
P1
R9 1K
VR1 VR-182C
R19 10K
U4 OP-27
C7 .1uF
C8 .1uF
Vref1 1.500V
1K R10
VR2 VP-182C
Vref2 2.455V
GEORGIA TECH RESEARCH INSTITUTE
Title
HOT LOAD TEMPEPATUPE MONITOR
Size A
Document Number A8013/007
REV 0
Date: April 19, 1990
Sheet 1 of 1



MV-1606 POWER

+15V ON PIN 1
-15V ON PIN 27
GND ON PIN 12

GEORGIA TECH RESEARCH INSTITUTE			
Title: COLD LOAD TEMPERATURE MULTIPLEXER			
Size: A	Document Number: A8013/008		REV: 0
Date: April 19, 1990	Sheet 1 of 1		



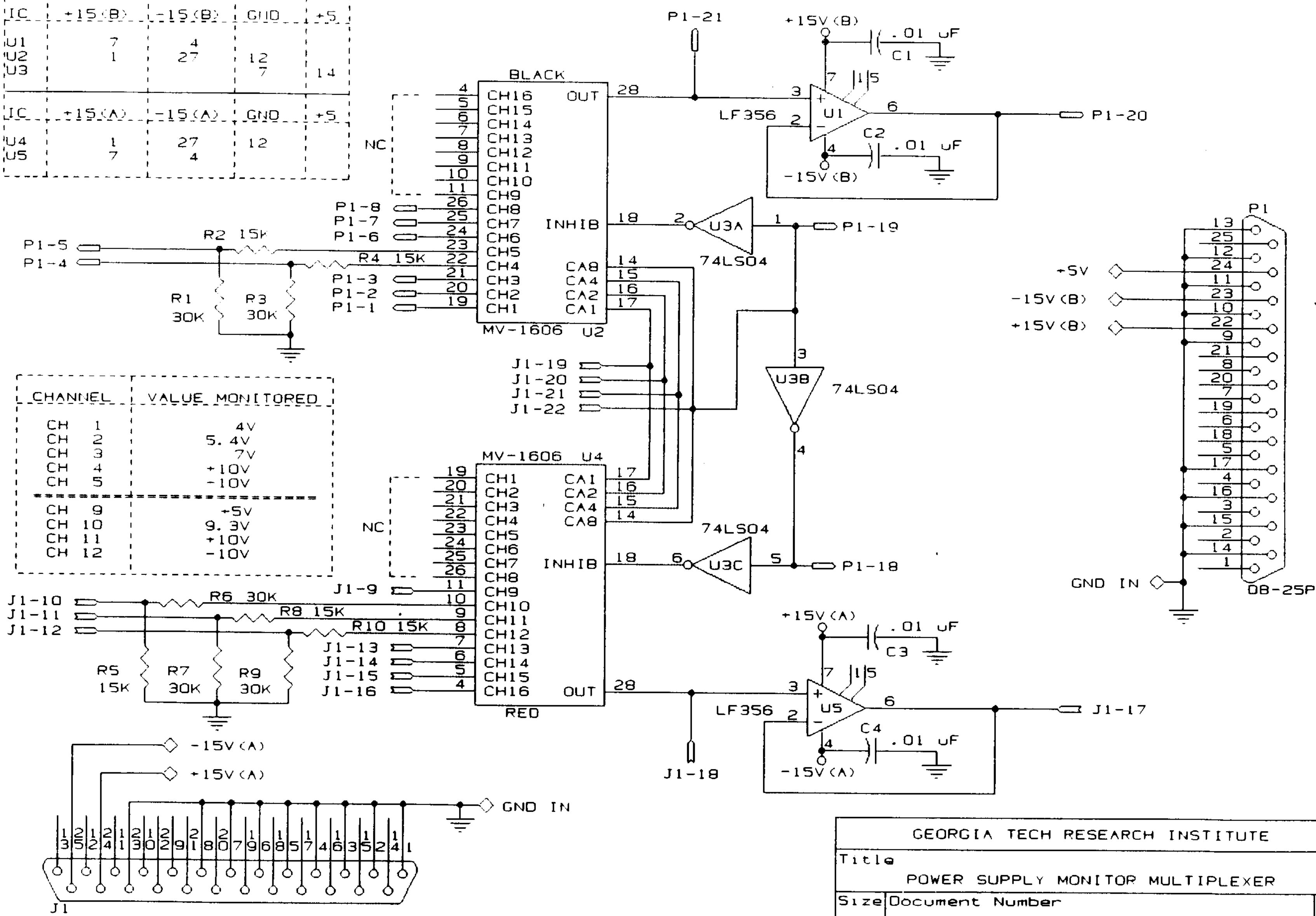
MV-1606 POWER

+15V ON PIN 1
-15V ON PIN 27
GND ON PIN 12

GEORGIA TECH RESEARCH INSTITUTE		
Title: HOT LOAD TEMPERATURE MULTIPLEXER		
Size: A	Document Number: A8013/009	REV: 0
Date: April 19, 1990	Sheet 1 of 1	

POWER CHART				
IC	+15(B)	-15(B)	GND	+5
U1 U2 U3	7 1	4 27	12 7	14
IC	+15(A)	-15(A)	GND	+5
U4 U5	1 7	27 4	12	

CHANNEL	VALUE MONITORED
CH 1	4V
CH 2	5.4V
CH 3	7V
CH 4	+10V
CH 5	-10V
CH 9	+5V
CH 10	9.3V
CH 11	+10V
CH 12	-10V



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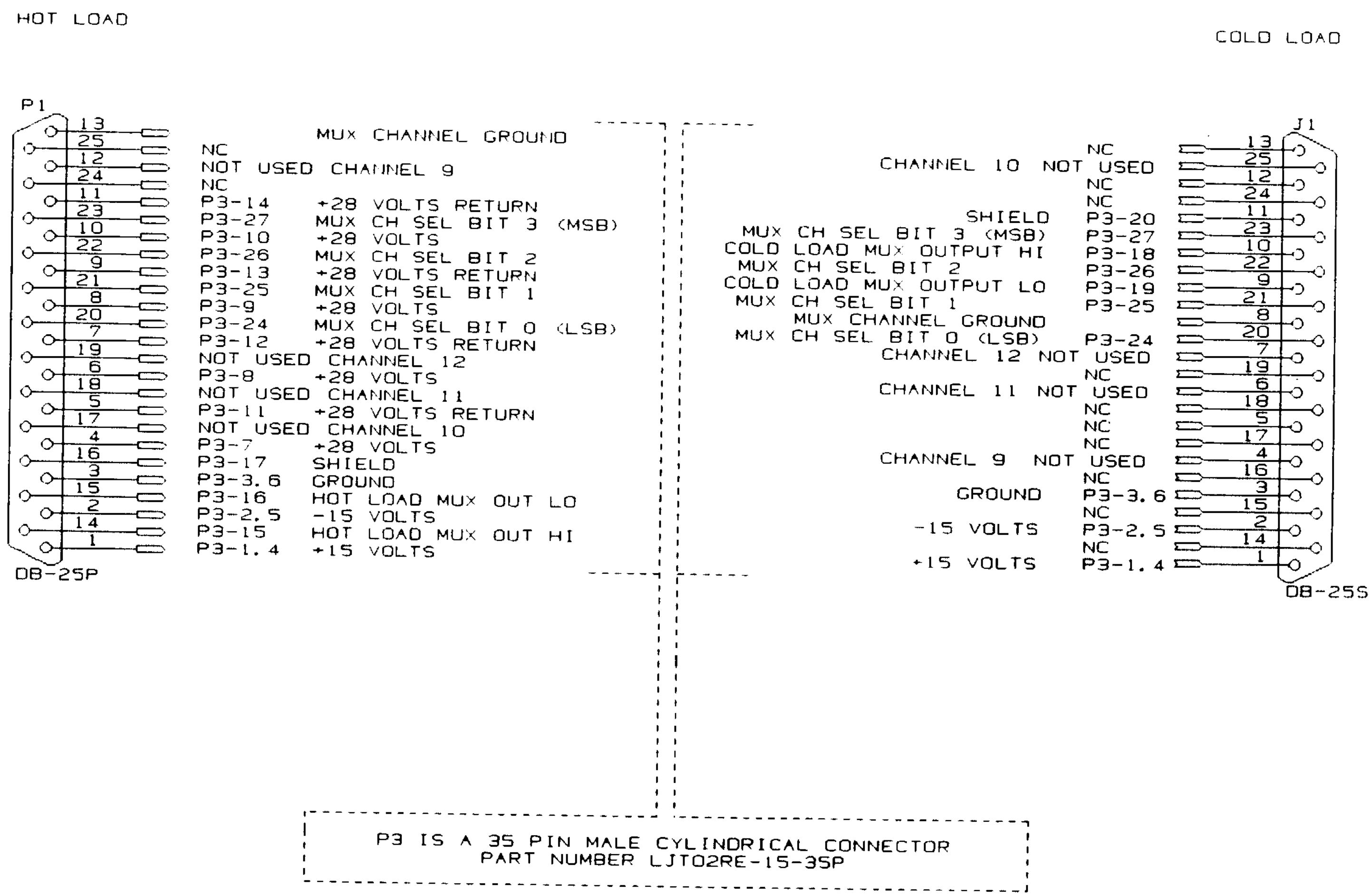
Title: POWER SUPPLY MONITOR MULTIPLEXER		
Size: A	Document Number: A8013/010	REV: 0
Date: April 19, 1990	Sheet of 1	



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Title: TEMPERATURE BREAKOUT BOX		
Size: A	Document Number: A8013-011	REV: 0
Date: April 19, 1990	Sheet 1 of 1	

APPENDIX C

VENDOR SUPPLIED SPARE PARTS LIST

AMPR SPARE PARTS LIST FOR VENDOR SUPPLIED ITEMS

Vendor	Item	Part No.	Price	As Of
Spacek Labs (805/564-4404)	10.7 GHz Downconverter	R10.7-U(50)	$ 3,950	August 1988
Spacek Labs	19.35 GHz Downconverter	R19.35-60	$ 4,050	March 1989
Spacek Labs	37.1 GHz Downconverter	R37.1-60	$ 4,410	March 1989
Miteq, Inc. (516/436-7400)	1.4 GHz IF Amplifier	AFS3-00100150-20-10P	$ 625	August 1988
Miteq, Inc.	0.1 GHz RF Preamplifier	AMP-3S-105108-20	$ 1,400	September 1988
Alpha Industries (617/682-4661)	85.5 GHz RF Mixer	9603 W17AR	$ 5,065	July 1988
Zax MMW Corp. (714/599-6159)	85.5 GHz Gunn Diode Oscillator	ZMT 10/20/85.5/0.5	$ 2,450	July 1988
Gamma-F Corp. (213/539-6704)	37.1 GHz Reject Filter	LPF-42	$ 840	November 1989
Superior Electric Co. (203/582-9561)	Stepper Motor With Encoder	M112FD8012 (MTR), C3A (Encoder)	$ 1,145	October 1988

APPENDIX D

AMPR CABLE INTERCONNECT DIAGRAMS

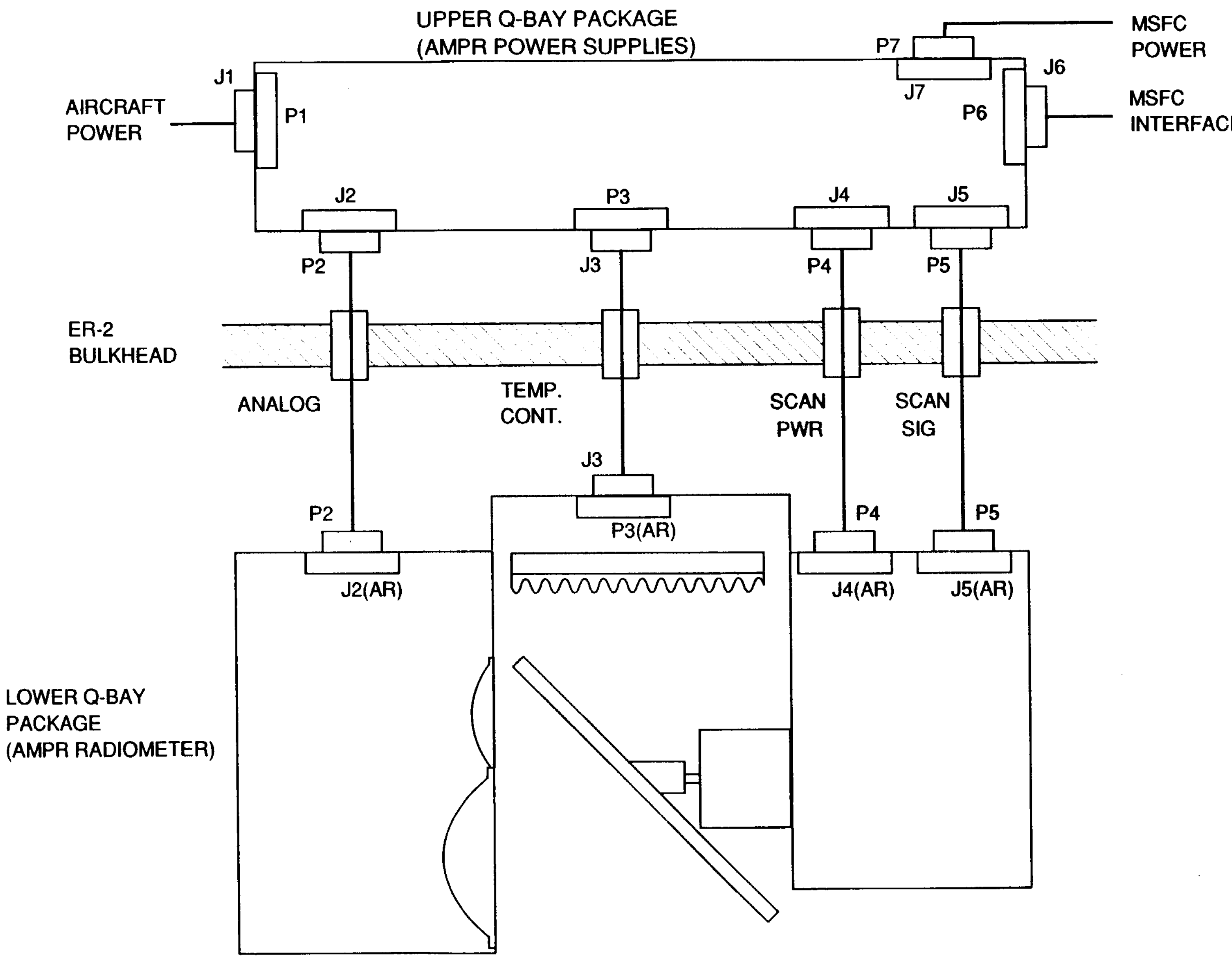

Figure D1. AMPR/ER-2 Cable Interconnect Diagram

TABLE D1. AMPR INTERCONNECT CABLE DESIGNATIONS AND PART NUMBERS

	Cable End		Box End	
Function	Desig.	Part No.	Desig.	Part No.
A/C power	(J1)	PT06CE-22-21S	(P1)	PT02SE-22-21P
Analog	(P2)	MS3126F22-55P	(J2)	MS3120F22-55S
Temp. Cont.	(J3)	LJT06RT-15-35S	(P3)	LJT02RE-15-35P
Scan Pwr.	(P4)	LJT06RT-15-18P	(J4)	LJT07RT-15-18S
Scan Sig.	(P5)	PT06SE-16-26P	(J5)	PT07CE-16-26S
MSFC Sig.	(J6)	MS3126F22-55S	(P6)	MS3122E22-55P
MSFC Pwr.	(P7)	LJT06RT-17-26P	(J7)	LJT07RT-17-26S

TABLE D2. ANALOG SIGNAL J2(AR) PIN DESIGNATIONS

Pin		Designation
A	+12 Vdc	Power supply GDO
B	+12 Vdc return	Power supply GDO
C	+ 5.4 Vdc	85.5 GDO monitor
D	+ 5.4 Vdc return	85.5 GDO monitor
E	NC	
F	NC	
G	+4 Vdc	37.1 GDO monitor
H	+ 4 Vdc return	37.1 GDO monitor
J	NC	
K	NC	
L	+7 Vdc	19.35 GDO monitor
M	+7 Vdc return	19.35 GDO monitor
N	+15 Vdc	Analog power supply
P	-15 Vdc	Analog power supply
R	Return	Analog power supply
S	+15 Vdc	Power supply monitor
T	-15 Vdc	Power supply monitor
U	Return	Power supply monitor
V	10.7 GHz data (high)	
W	10.7 GHz data (low)	
X	10.7 GHz data (shield)	
Y	19.35 GHz data (high)	
Z	19.35 GHz data (low)	
a	19.35 GHz data (shield)	
b	37.1 GHz data (high)	
c	37.1 GHz data (low)	
d	37.1 GHz data (shield)	
e	85.5 GHz data (high)	
f	85.5 GHz data (low)	
g	85.5 GHz data (shield)	

Pin	Designation
h	NC
i	NC
j	NC
k	NC
l	NC
n	NC
p	NC
q	NC
r	NC
s	Sample/hold input (high)
t	Sample/hold input (low)
u	NC
v	Integrate/dump input (high)
w	Integrate/dump input (low)
x	NC
y	NC
z	NC
AA	NC
BB	NC
CC	NC
DD	NC
EE	NC
FF	NC
GG	NC
HH	Chassis ground

TABLE D3. TEMPERATURE CONTROL P3(AR) PIN DESIGNATIONS

Pin	Designation		Pin	Designation
1	+15 Vdc	Temperature monitor/control power supply	30	NC
2	-15 Vdc		31	NC
3	Return		32	NC
4	+15 Vdc	Power supply monitor	33	NC
5	-15 Vdc		34	NC
6	Return		35	NC
7	+28 Vdc	From aircraft power	36	NC
8	+28 Vdc		37	NC
9	+28 Vdc			
10	+28 Vdc			
11	+28 Vdc return			
12	+28 Vdc return			
13	+28 Vdc return			
14	+28 Vdc return			
15	Hot load temperature multiplexer (high)			
16	Hot load temperature multiplexer (low)			
17	Hot load temperature multiplexer (shield)			
18	Cold load temperature multiplexer (high)			
19	Cold load temperature multiplexer (low)			
20	Cold load temperature multiplexer (shield)			
21	NC			
22	NC			
23	NC			
24	Hot/cold load multiplexer select bit 0 (LSB)			
25	Hot/cold load multiplexer select bit 1			
26	Hot/cold load multiplexer select bit 2			
27	Hot/cold load multiplexer select bit 3 (MSB)			
28	NC			
29	NC			

TABLE D4. SCAN POWER J4(AR) PIN DESIGNATIONS

Pin		Designation
A	+28 Vdc	Scanner power supply
B	+28 Vdc	
C	+28 Vdc return	
D	+28 Vdc return	
E	+28 Vdc	Power supply monitor
F	NC	
G	+5 Vdc	Digital power supply
H	+5 Vdc return	
J	+5 Vdc	Power supply monitor
K	+5 Vdc return	
L	NC	
M	NC	
N	NC	
P	NC	
R	NC	
S	NC	
T	NC	
U	NC	

TABLE D5. SCAN SIGNAL P5(AR) PIN DESIGNATIONS

Pin	Designation
A	Data valid out (high)
B	Data valid out (low)
C	Scan mode select bit 0 (LSB)
D	Scan mode select bit 1
E	Scan mode select bit 2
F	Scan position data bit 0 (LSB)
G	Scan position data bit 1
H	Scan position data bit 2
J	Scan position data bit 3
K	Scan position data bit 4
L	Scan position data bit 5
M	Scan position data bit 6
N	Scan position data bit 7 (MSB)
P	Integrate/dump out (high)
R	Integrate/dump out (low)
S	Sample/hold out (high)
T	Sample/hold out (low)
U	Scan mode select ground
V	Scan mode select bit 3 (MSB)
W	NC
X	NC
Y	NC
Z	NC
a	NC
b	NC
c	NC